Fire Detection and Alarm Systems

Photo courtesy of Rich Mahaney.

Chapter Contents

chapter 14

Key Terms

NFPA® Job Performance Requirements

This chapter provides information that addresses the following job performance requirements of NFPA® 1031, *Standard for Professional Qualifications for Fire Inspector and Plan Examiner* (2014).

Fire Inspector I	Fire Inspector II
4.3.6	5.3.4
	5.4.3
	5.44

Fire Detection and Alarm Systems

Learning Objectives

After reading this chapter, students will be able to:

Inspector I

1. Identify fire alarm system components. (4.3.6)
2. Explain types of alarm-signaling systems. (4.3.6)
3. Explain types of automatic alarm-initiating devices. (4.3.6)
4. Describe manual alarm-initiating devices. (4.3.6)
5. Describe service testing and inspection methods for fire detection and alarm systems. (4.3.6)

Inspector II

1. Explain methods to evaluate fire detection and suppression system equipment for life safety, property conservation and hazards. (5.3.4, 5.4.3)
2. Describe inspection and testing methods for fire detection and suppression system equipment. 5.4.4

Chapter 14
Fire Detection and Alarm Systems

Case History

Athens, Georgia, 2014: An investigation by the student newspaper at the University of Georgia revealed numerous expired fire extinguishers on campus. A total of 57 fire extinguishers in the labs, classrooms, and hallways of 19 buildings were checked; 46 of the extinguishers were expired and had not been checked in more than a year. Annual checks for many of the more than 8,000 extinguishers on campus had slowed considerably because of difficulties in contracting with an outside company. After the story came to light, a company was quickly contracted to start the process of checking, servicing, and replacing extinguishers. The Safety Division was also working to implement an electronic database to keep track of the extinguishers on campus.

History has proven that early detection of a fire and the signaling of an appropriate alarm remain significant factors in preventing large losses due to fire. Properly installed and maintained fire detection and alarm systems can help to increase the survivability of occupants and emergency responders while decreasing property losses (**Figure 14.1**).

Together with automatic fire suppression systems, fire detection and alarm systems are part of the active fire protection systems found in many occupancies. To this end, adopted building and/or fire codes may require the installation of fire detection and alarm systems. These systems usually require installation and maintenance by trained individuals.

Figure 14.1 Large-loss fires can often be prevented when there is little or no delay between detection and alarm transmission.

This chapter provides information on the fundamental components of fire detection and alarm systems. Addressed in more detail are fire alarm control units, detection and alarm system components, types of signals, alarm-initiating devices, and notification appliances. This chapter also highlights the procedures that fire inspectors or other personnel should follow while inspecting and testing these systems. Also described is the importance of preparing and maintaining accurate records regarding the installation, testing, modification, and maintenance of fire detection and alarm systems.

I

Fire Alarm System Components

Modern detection and signaling systems vary in complexity from those that are simple to those that incorporate advanced detection and signaling equipment. Such systems are typically designed and installed by qualified individuals as determined by the AHJ. The design, installation, and approval of a fire detection and alarm system may also require acceptance testing by regulatory agencies before new buildings are occupied or the system is placed in service.

The design and installation of the fire detection and alarm system should conform to applicable provisions of NFPA® 70, National Electrical Code®, and NFPA® 72, National Fire Alarm and Signaling Code, and locally adopted codes and ordinances. Other standards also apply to the installation of these systems and are addressed later in this chapter within the discussions of the various types of systems. Each of the following sections highlights a basic component of a fire detection and alarm system.

Fire Alarm Control Unit (FACU) — The main fire alarm system component that monitors equipment and circuits, receives input signals from initiating devices, activates notification appliances, and transmits signals off-site. Formerly called the *fire alarm control panel (FACP).*

Fire Alarm Control Units

The **fire alarm control unit (FACU)**, formerly called the fire alarm control panel (FACP), contains the electronics that supervise and monitor the integrity of the wiring and components of the fire alarm system. The FACU basically serves as the brain for the alarm system **(Figure 14.2)**. It receives signals from alarm-initiating devices, processes the signals, and produces output signals that activate audible and visual appliances. The FACU also transmits signals to an off-site monitoring station when provided. Power and fire alarm circuits are connected directly into this panel. In addition, the remote auxiliary fire control units and notification appliance panels are considered to be part of the fire alarm system and are connected and controlled.

Controls for the system are located in the FACU **(Figure 14.3, p. 610)**. The FACU can also perform other functions, such as:

- Providing two-way firefighter communication
- Providing remote annunciator integration
- Controlling elevators, HVAC, fire doors, dampers, locks, or other fire protection features

The FACU can also provide public address messages and mass notifications alerts through prerecorded evacuation messages or independent voice communications.

NOTE: Some fire alarm control units are designed for both security and fire protection. In these types of systems, fire protection is engineered into the system to assume the highest priority.

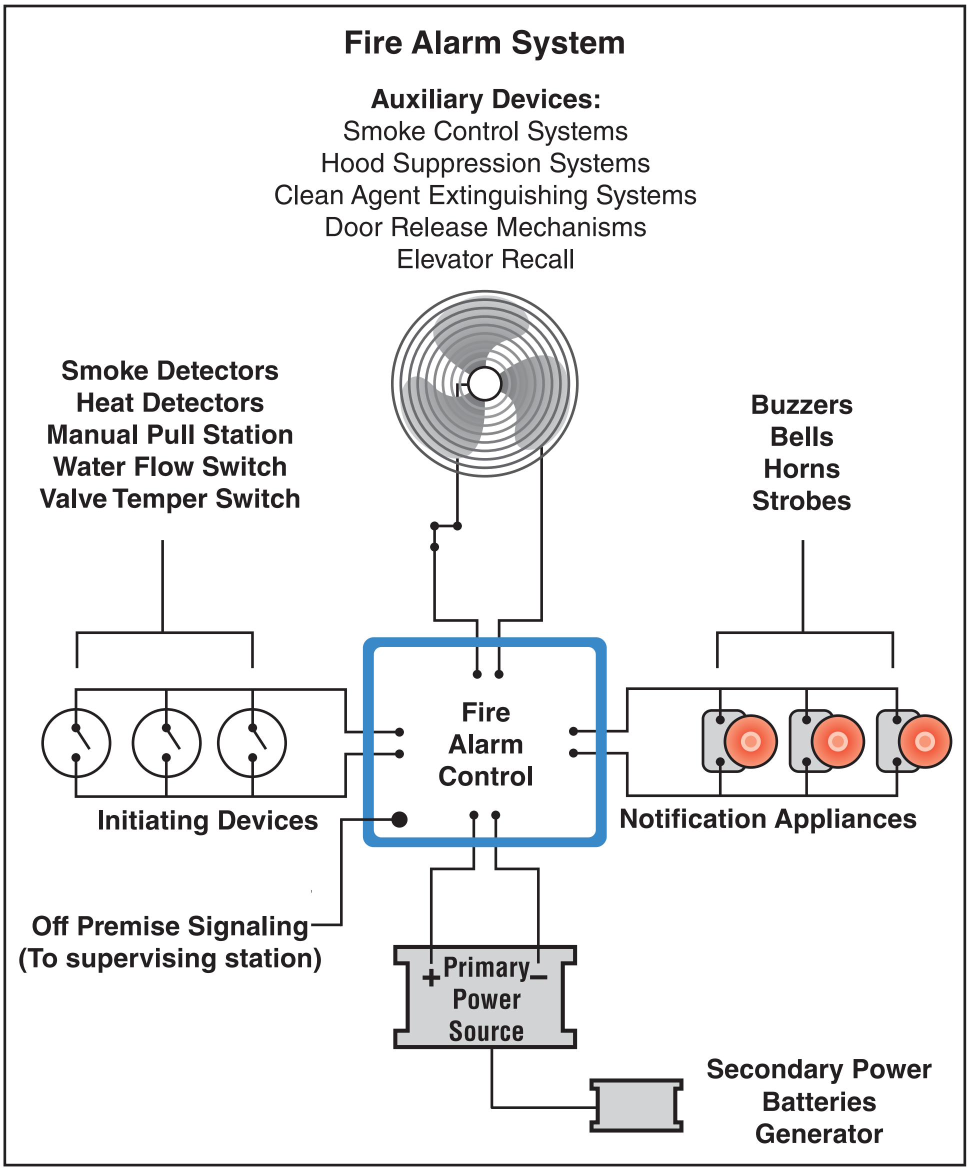


Figure 14.2 This schematic shows the different components of a fire alarm control unit (FACU), the central hub of an alarm system.

Primary Power Supply

The primary electrical power supply usually comes from the building's main power connection to the local utility provider. In rare instances where electrical service is unavailable or unreliable, an engine-driven generator can provide the primary power supply. If such a generator is used, either a trained operator must be on duty 24 hours a day or the system must contain multiple engine-driven generators. One of these generators must always be set for automatic starting. The FACU must supervise the primary power supply and signal an alarm if the power supply is interrupted **(Figure 14.4, p. 610)**.

Secondary Power Supply

All fire alarm systems must have a secondary power supply. This requirement is designed so that the system will be operational even if the main power supply fails. The secondary power supply must be capable of providing normal, (nonalarm) standby conditions capacity and power to fully operate an alarm condition. The time period requirements for secondary power operation capa-

Figure 14.3 An FACU can monitor alarms, control elevators, and public address messages.

Figure 14.4 On the power supply circuit board, one switch should be permanently labeled as the FACU (sticker in the photo) to ensure that anyone doing maintenance on the circuit board does not deactivate that switch and create a safety hazard.

bilities vary and can be found in NFPA® 72. Secondary power sources can consist of batteries with chargers, engine-driven generators with a storage battery, or multiple engine-driven generators, of which one must be set for automatic starting **(Figure 14.5)**.

Initiating Devices

A fire detection system consists of manual and automatic alarm-initiating devices that are activated by the presence of fire, smoke, flame, or heat **(Figure 14.6)**. The devices then send a signal to the FACU using one of two methods: a hard-wire system or a generated signal conveyed by radio wave over a special frequency to a radio receiver in the panel. Both automatic and manual alarm-initiating devices are addressed in more detail in the next sections and include but are not limited to the following devices:

- Manual pull stations
- Smoke detectors
- Flame detectors
- Heat detectors
- Combination detectors
- Waterflow devices

Notification Appliances

Audible notification signaling appliances are the most common types of alarm-signaling systems used for signaling a fire alarm in a structure. Once

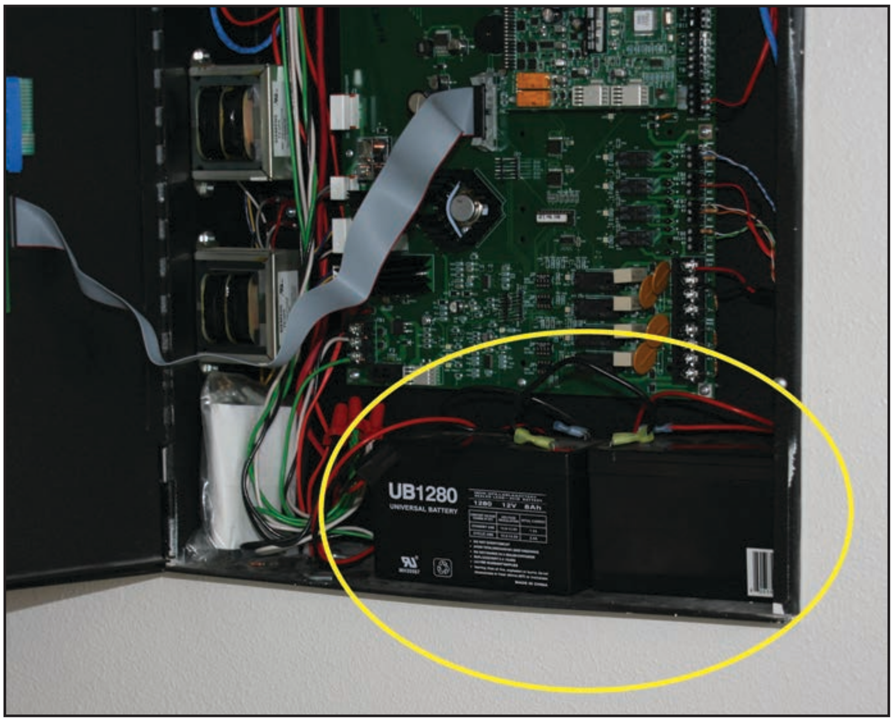


Figure 14.5 A backup battery, like the one under the circuit board in the photo, should be available to all components of a fire detection system if primary power is unavailable. *Courtesy of Ron Moore, McKinney (TX) Fire Department.*

Figure 14.6 A ceiling-mounted fire alarm speaker and strobe light combination unit.

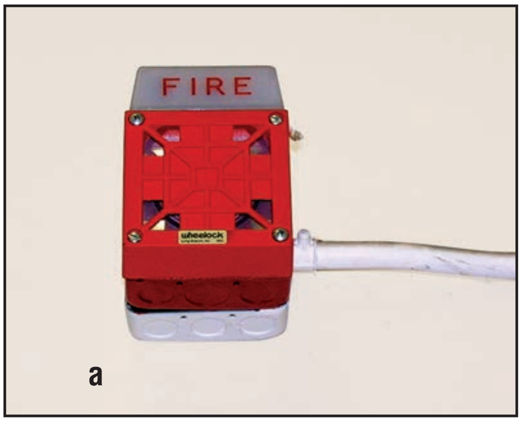
an alarm-initiating device is activated, it sends a signal to the FACU, which then processes the signal and initiates actions. The primary action initiated is usually local notification, which can take the form of:

- Bells
- Buzzers
- Horns
- Speakers
- Strobe lights
- Other warning appliances

Depending on the system's design, the local alarm may either activate a single notification appliance, notification appliances within a specific zone, designated floor(s), or the entire facility. Notification appliances fall under the following categories **(Figures 14.7 a-c, p. 612)**:

- **Audible** — Approved sounding devices, such as horns, bells, or speakers, that indicate a fire or emergency condition.
- **Visual** — Approved lighting devices, such as strobes or flashing lights, that indicate a fire or emergency condition.
- **Textual** — Visual text or symbols indicating a fire or emergency condition.
- **Tactile** — Indication of a fire or emergency condition through sense of touch or vibration.

NOTE: Audible appliances are described in more detail in **Appendix H**.



Figures 14.7 a-c Notification devices include bells, horns, strobe lights, and speakers.

Additional Alarm System Functions

Building codes have special requirements for some types of occupancies in case of fire. In these cases, the fire detection and alarm system can be designed to initiate the following actions:

Smoke Damper — Device that restricts the flow of smoke through an air-handling system; usually activated by the building's fire alarm signaling

- Turn off the heating, ventilating, and air-conditioning (HVAC) system
- Close **smoke dampers** and/or fire doors **(Figure 14.8)**
- Pressurize stairwells and/or operate smoke control systems for evacuation purposes
- Unlock doors along the path of egress
- Provide elevator recall to the designated floor and prevent normal operations **(Figure 14.9)**.
- Operate heat and smoke vents
- Activate special fire suppression systems, such as preaction and deluge sprinkler systems or a variety of special-agent fire extinguishing systems

Figure 14.8 Magnetic door closures like this one are designed to remain open during normal building activity and release when alarms are activated to close the door.

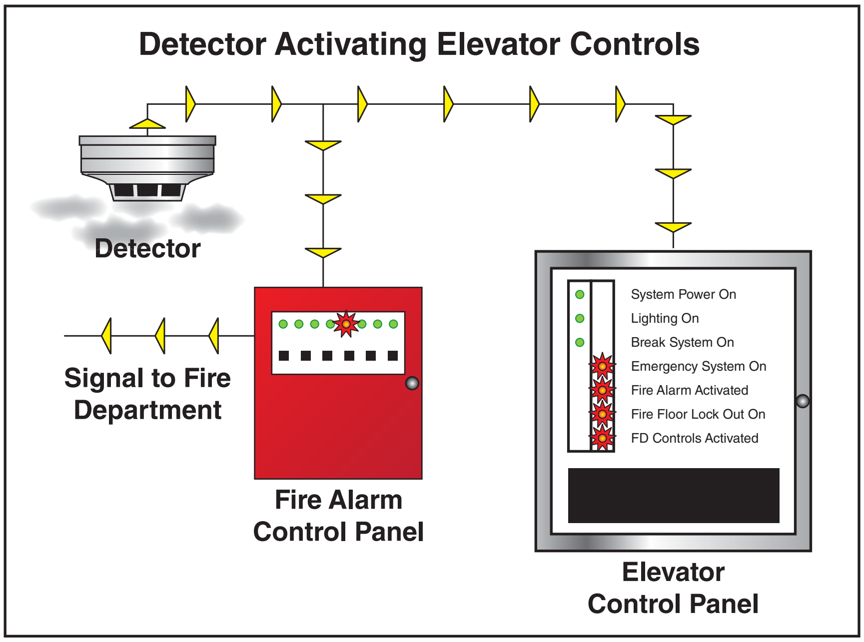


Figure 14.9 In this scenario, the activation of the fire detection system has caused an override of the elevator controls so that the elevator can be used by firefighters.

Alarm Signaling Systems

Fire detection and alarm systems are designed to receive certain types of signals from devices and perform an action based upon the type of signal received. Some signals may indicate a fire condition, while others may indicate that a device on the system needs to be serviced. The FACU should be programmed to respond to different signal types in an appropriate manner.

Fire detection and alarm systems are equipped with three types of specialty signals, depending on the type and nature of the alarm they are reporting:

- An **alarm signal** is a warning of a fire emergency or dangerous condition that demands immediate attention. Locally adopted codes may require fire alarm signals from systems monitored by a supervising station to notify the responding fire department. Activation of smoke detectors, manual pull stations, waterflow switches, and other fire extinguishing systems are all initiating devices that send fire alarm signals.
- A **supervisory signal** indicates an off-normal condition of the complete fire protection system. Supervisory signals also include a returned-to-normal signal, meaning that the condition has been resolved. These signals are used to monitor the integrity of the fire protection features of the system.
- A **trouble signal** indicates a problem with a monitored circuit or component of the fire alarm system or the system's power supply. Each signal must be audibly and visually displayed at the FACU in a distinct manner that differentiates one type of signal from another. Trouble conditions include loss of primary power or failure or removal of an initiating device, such as a smoke detector.

Alarm Signal — Signal given by a fire detection and alarm system when there is a fire condition detected.

Supervisory Signal — Signal given by a fire detection and alarm system when a monitored condition in the system is off-normal.

Trouble Signal — Signal given by a fire detection and alarm system when a power failure or other system malfunction occurs.

NOTE: A trouble signal indicates a problem with the fire detection and alarm system. A supervisory alarm indicates a problem with an accessory of the fire alarm system.

Tamper Switches

Tamper switches are devices used to supervise indicating valves installed in a fire protection water supply system. These switches monitor water shutoff valves that supply the sprinkler system. If a water shutoff valve within the water-based fire protection system — such as an automatic fire sprinkler system, standpipe, static tank, or fire pump — is closed, a supervisory signal is annunciated at the FACU and transmitted to a supervising station.

A simple fire alarm system may only sound a local evacuation alarm. A more complex system may sound a local alarm, activate building services, and notify fire and security agencies to respond. The type of system required depends upon the type of occupancy of the building and is affected by the following factors:

- Level of life safety hazard
- Structural features of the building
- Hazard level presented by the contents of the building
- Availability of fire suppression resources, such as water supply, hydrants, and automatic sprinkler systems
- State and local code requirements

Inspectors should be able to recognize each type of system and understand how each system operates. This recognition is important when performing inspections or conducting preincident planning. Several types of systems include the following:

- Protected premises (local)
- Supervising station alarm systems
- Public emergency alarm reporting system
- Emergency communications systems

Both emergency communications systems and parallel telephone systems may be found in buildings with certain occupancies or building types. Mass notification systems are a special type of emergency communications systems that may be found as a part of a building's alarm system to provide specific and detailed instructions to a building's occupants. NFPA® 72 contains the requirements for all fire alarm and protective signaling systems and should be consulted for further information. The following section describes the major systems.

Protected Premises System — Alarm system that alerts and notifies only occupants on the premises of the existence of a fire so that they can safely exit the building and call the fire department. If a response by a public safety agency (police or fire department) is required, an occupant hearing the alarm must notify the agency.

Protected Premises Systems (Local)

A **protected premises system** is designed to provide notification to building occupants only on the immediate premises **(Figure 14.10)**. Where these systems are allowed, there are no provisions for automatic off-site reporting.

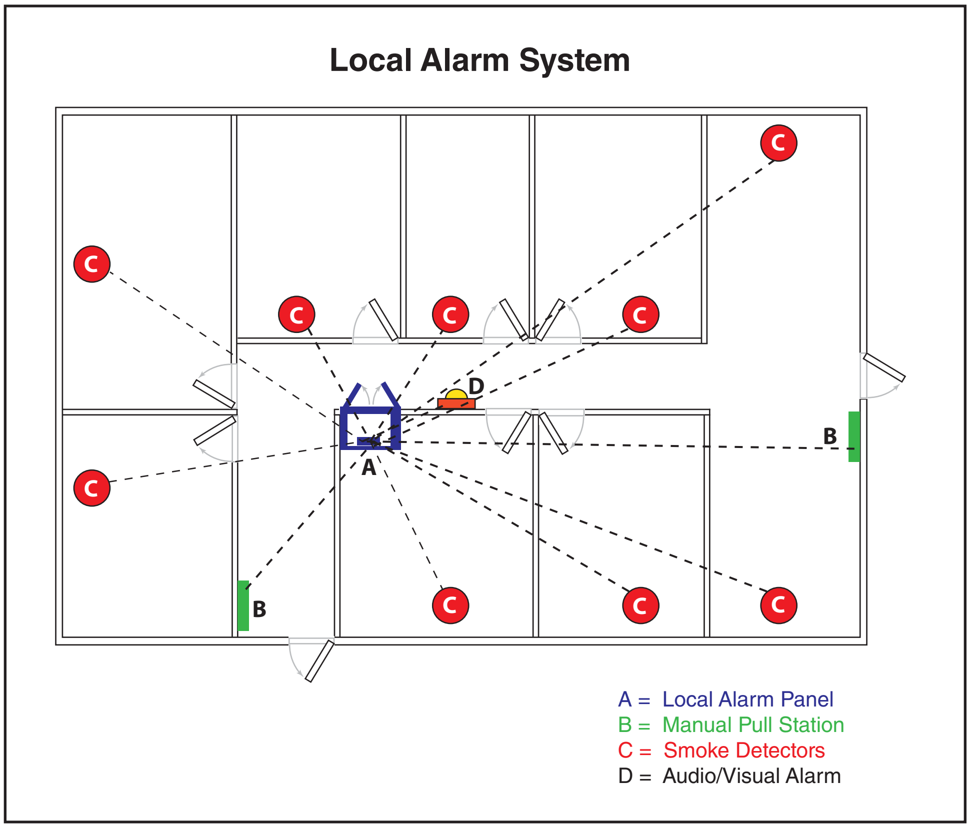


Figure 14.10 A local alarm system alerts occupants of one building to an incident occurring on that property.

The protected premises system can be activated by manual means, such as a pull station, or by automatic devices, such as smoke detectors. A protected premises system may also be capable of annunciating a supervisory or trouble condition to ensure that service interruptions do not go unnoticed.

Presignal Alarms

Presignal alarms are unique systems that may be employed in locations such as hospitals where occupants need assistance to evacuate in a safe and orderly manner. This presignal is usually a separate signal that is recognizable only by personnel who are familiar with the system. The presignal may be a recorded message over an intercom, a soft alarm signal, or a pager notification. Depending on the policies of the occupancy and local code requirements, emergency personnel may elect to handle the incident without sounding a general alarm. Emergency responders may sound the general alarm after investigating the problem, or the general alarm will sound automatically after a certain amount of time has passed and the fire alarm control unit has not been reset.

Conventional Alarm Systems

A conventional system is the simplest type of protected premises alarm system. When an alarm-initiating device, such as a smoke detector, sends a signal to the FACU, all of the alarm-signaling devices operate simultaneously **(Figure 14.11, p. 616)**. The signaling devices usually operate continuously until the FACU is reset. The FACU is incapable of identifying which initiating device

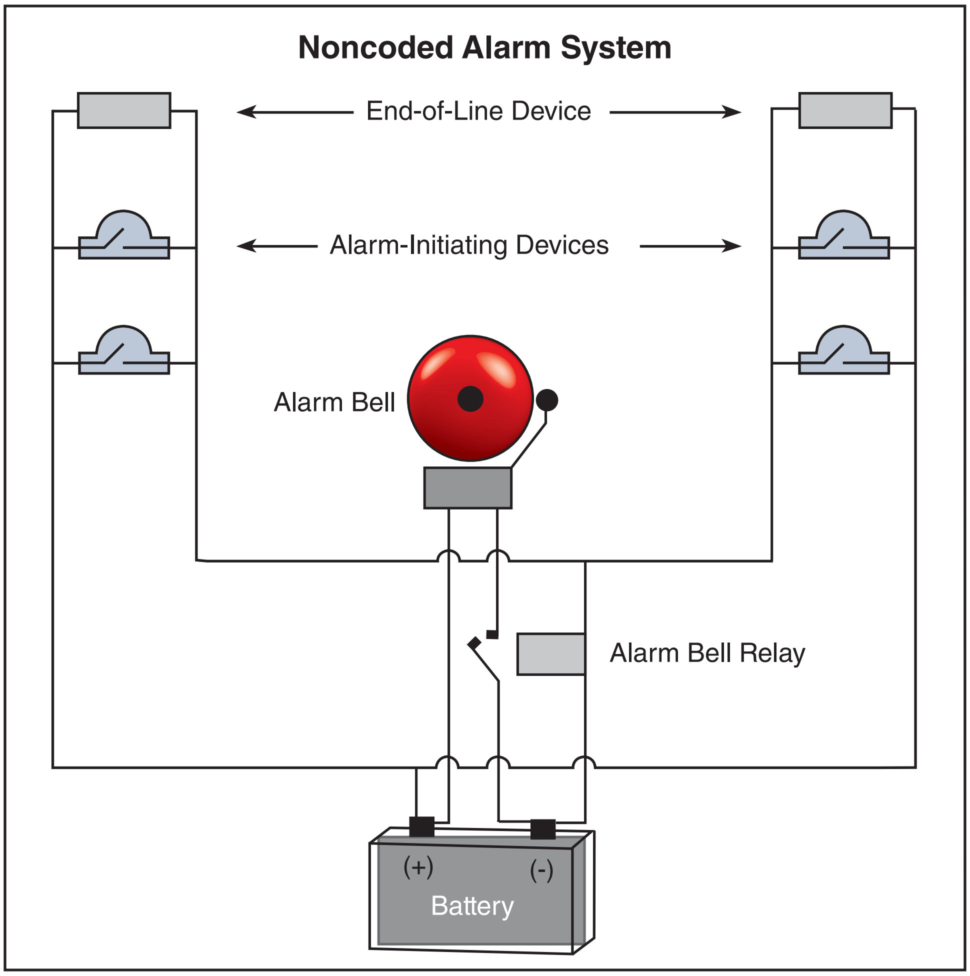


Figure 14.11 In conventional alarm systems, all the individual alarm appliances operate at the same time.

triggered the alarm; therefore, building and fire department personnel must walk around the entire facility and visually check to see which device was activated. These systems are only practical in small occupancies with a limited number of rooms and initiating devices.

An FACU serves the premises as a local control unit. This system is found in occupancies that use the alarm signals for other purposes. In the past, schools sometimes used the same bells for class change as for fire alarms. The FACU enables the fire alarm to have a sound that is distinct from class bells, eliminating confusion as to which type of alarm is sounding. Modern codes do not allow systems such as these; however, older systems that do are still encountered.

Zoned Conventional Alarm Systems

Fire-alarm system annunciation enables emergency responders to identify the general location, or zone, of alarm device activation. In this type of system, an annunciator panel, FACU, or a printout visibly indicates the building, floor, fire zone, or other area that coincides with the location of an operating alarm-initiating device **(Figure 14.12)**.

Alarm-initiating devices in common areas are arranged in circuits or zones. Each zone has its own indicator light or display on the FACU. When an initiating device in a particular zone is triggered, the notification devices are activated, and the corresponding indicator is illuminated on the FACU. This signal gives responders a better idea of where the problem is located.

NOTE: A zone is a defined area within the protected premises.

An annunciator panel may be located remotely from the FACU, often in a location designated by the fire department. Such an installation may be found at the driveway approach to a large residential retirement complex, for example. This type of annunciator panel usually has a map of the complex coordinated to the zone indicator lamps. Arriving firefighters use the information provided on the annunciator panel to locate the building involved. Another type of annunciator panel may be found in the lobby area of a building. It will have a graphic display of the involved area.

Figure 14.12 Zoned systems are designed to help emergency responders quickly identify the location of a fire.

Older Coded Fire Alarm Systems

A coded system may also be equipped with its own indicator lamp on the FACU, a signal-coding device that is placed into the circuit. This device causes the signaling devices to sound in a unique pattern for each zone. This pattern enables employees or fire department personnel to determine the problem zone by listening to the pattern of the alarms. This is not permitted in new installations, but may exist in older installations.

Usually, the audible pattern consists of a series of short rings, a brief pause, and a second series of short rings, followed by a long pause. The cycle then repeats. Most systems are designed to sound the alarm for the first zone that comes in and then disregard all subsequent zones that initiate alarm signals.

Addressable Alarm Systems

Addressable alarm systems display the location of each initiating device on the FACU and an annunciator panel if provided (**Figure 14.13**). This connection enables emergency responders to pinpoint the specific device that has been activated. Addressable systems reduce the amount of time that it takes to respond to emergency situations. These systems also allow repair personnel to quickly locate and correct malfunctions in the system.

Figure 14.13 Addressable alarms display the location of each initiating device.

Supervising Station Alarm Systems

Fire alarm systems are required by model fire codes to be monitored at a constantly attended location. For buildings that are not constantly attended by qualified personnel, initiating device signals are required to be transmitted to a supervising station. A supervising station is a facility that receives signals from a protected premises fire alarm system and where the signal is processed by personnel.

NFPA® 72 designates supervising stations as:

- **Central** — A central supervising station is an independent business that is also listed by a nationally recognized testing laboratory. A central station is recognized as the most reliable type of supervising station.
- **Proprietary** — A proprietary supervising station is a supervising station under the same ownership as the buildings protected by the fire alarm systems. At a proprietary supervising station, personnel are constantly in attendance to supervise and investigate fire alarm system signals.
- **Remote** — A remote supervising station is not listed and operates as a business. Personnel are in attendance at all times to supervise and investigate signals.

Central Station System — Alarm system that transmits a signal to a constantly attended location (central station) operated by an alarm company. Alarm signals from the protected property are received in the central station and are then retransmitted by trained personnel to the fire department alarm communications center.

Central Station System

A **central station system** is a listed supervising station that monitors the status of protected premises alarm systems and provides inspection, testing, and maintenance through contracted services **(Figure 14.14)**.

Typically, a central station is a company that sells its services to many customers. When an alarm is activated at a particular client's location, central station employees receive that information and contact the fire department and representatives of the occupancy. The alarm systems at the protected property and the central station are most commonly connected by dedicated telephone lines. All central station systems should meet the requirements set forth in NFPA® 72. When meeting the listing requirements, central stations must be listed by UL.

The primary difference between a central station system and a proprietary system is that the receiving point for alarms in a central station system is located outside the protected premises and is monitored by a contracted service **(Figure 14.15)**. The external receiving point is called the central station.

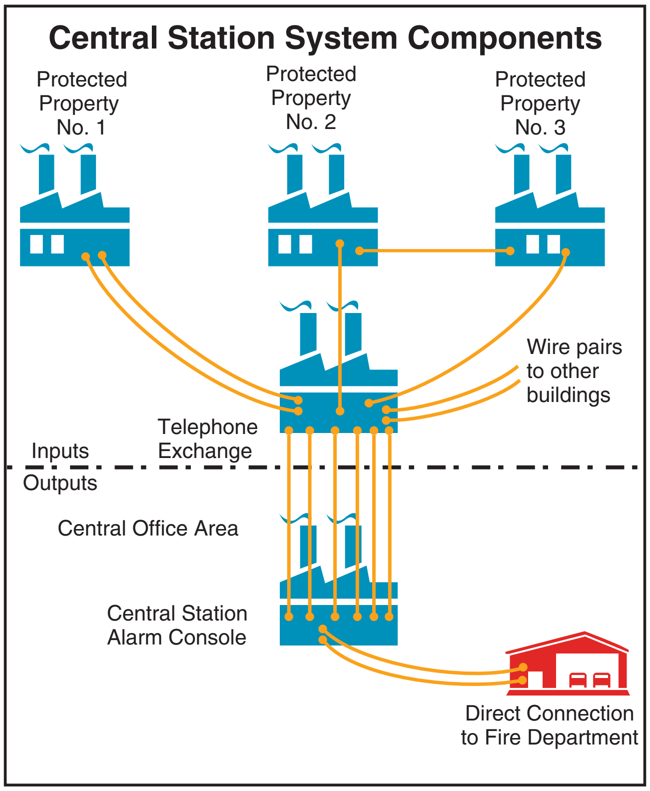


Figure 14.14 Multiple properties can be monitored in a central station system.

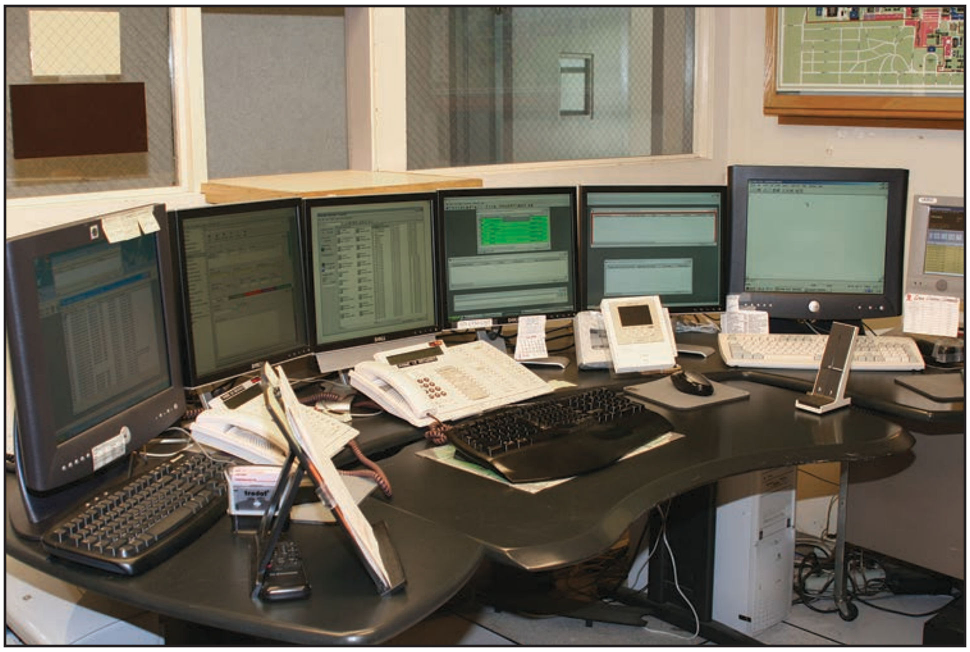


Figure 14.15 Central station receiving sites are housed in an off-site location that receives alarms and routes them to the responding fire department.

Proprietary System

A **proprietary system** is used to protect large commercial and industrial buildings, high-rise structures, and groups of commonly owned facilities, such as a college campus or industrial complex in single or multiple locations. Each building or area has its own system that is wired into a common receiving point that the facility owner owns and operates. The receiving point must be in a separate structure or a part of a structure that is remote from any hazardous operations **(Figure 14.16, p. 620)**.

Proprietary Alarm System — Fire alarm system owned and operated by the property owner.

The receiving station of a proprietary system is continuously staffed by trained personnel who can take necessary actions upon alarm activation. The operator should be able to automatically summon a fire department response through the system controls or by using the telephone. Many proprietary systems and receiving points are used to monitor security functions in addition to fire and life safety functions. Modern proprietary systems can be complex and have a wide range of capabilities, including:

- Coded-alarm and trouble signal indications
- Building utility controls
- Elevator controls
- Fire and smoke damper controls

Remote Receiving System

A listed supervising station that monitors the status of protected premise alarm systems through contracted services is called a **remote receiving station**. Remote receiving stations do not provide inspection, testing, or maintenance services.

Remote Receiving System — System in which alarm signals from the protected premises are transmitted over a leased telephone line to a remote receiving station with a 24-hour staff; usually the municipal fire department's alarm communications center sending an alarm signal to the FACU.

Parallel Telephone and Multiplexing Systems

A parallel telephone system consists of a dedicated circuit between each individual alarm box or protected property and the fire department telecommunications center. NFPA® 72 requires that these telephone systems are not used for any other purpose than to relay alarms. These systems are generally not found today due to the existence of private monitoring firms.

Multiplexing systems allow the transmission of multiple signals over a single line. This type of system allows the alarm initiating devices to be identified individually, as in an addressable system, or in a group through the interaction of the fire alarm control unit with each independent device. Remote devices, such as relays, can be controlled over the same line to which initiating and indicating devices are connected. This connection greatly reduces the amount of circuit wiring needed for large applications.

The control panels for multiplexing systems can range from the simple and relatively inexpensive to the sophisticated and costly. Some multiplex systems have the added advantage of being able to test the performance of the devices, reducing manpower requirements for preventive maintenance.

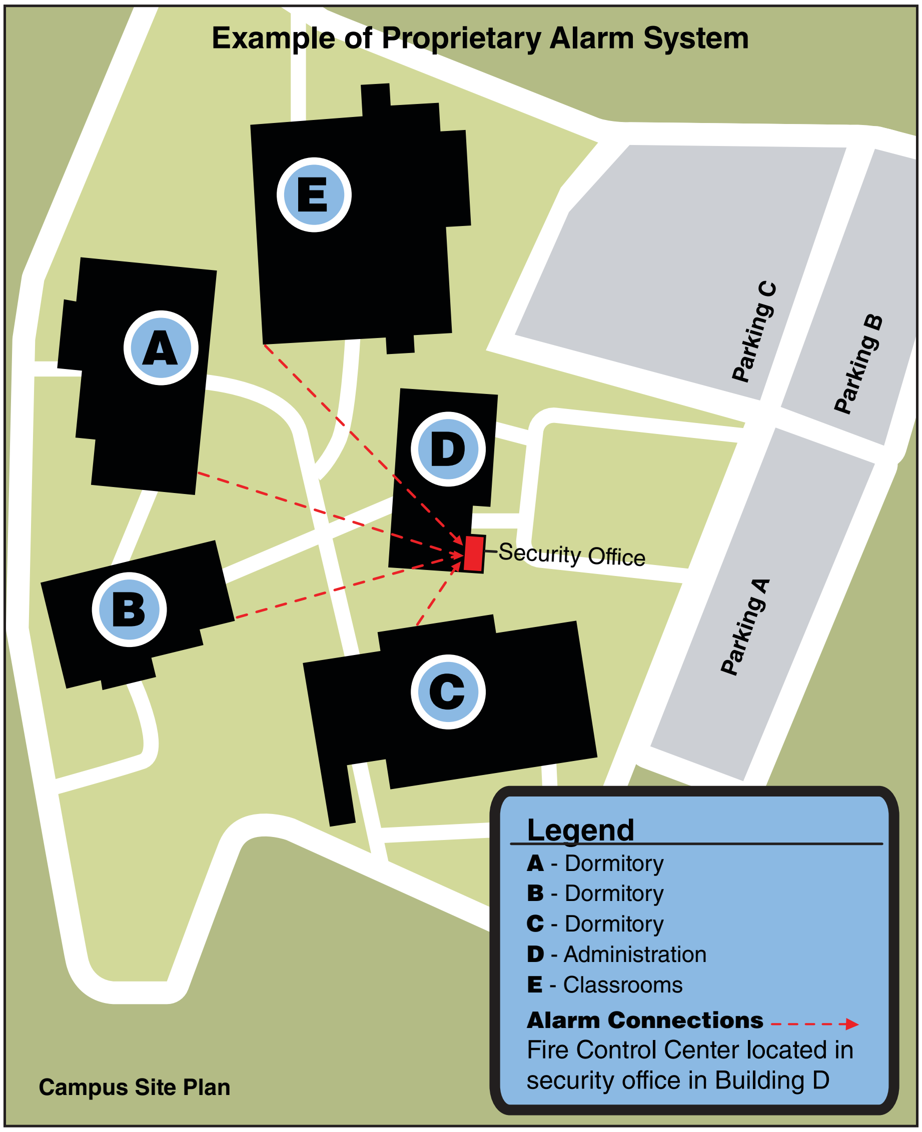


Figure 14.16 A proprietary alarm system is used to monitor several commonly owned facilities, such as a number of university buildings, with one receiving point.

Depending on local requirements, the fire department may approve other organizations to monitor the remote system. In some small communities, the local emergency services telecommunications center monitors the system **(Figure 14.17)**. This arrangement is particularly common in communities that have volunteer fire departments whose stations are not continuously staffed. In these cases, emergency services telecommunications personnel must be aware of the importance of these alarm signals and trained in the actions that must be taken upon alarm receipt.

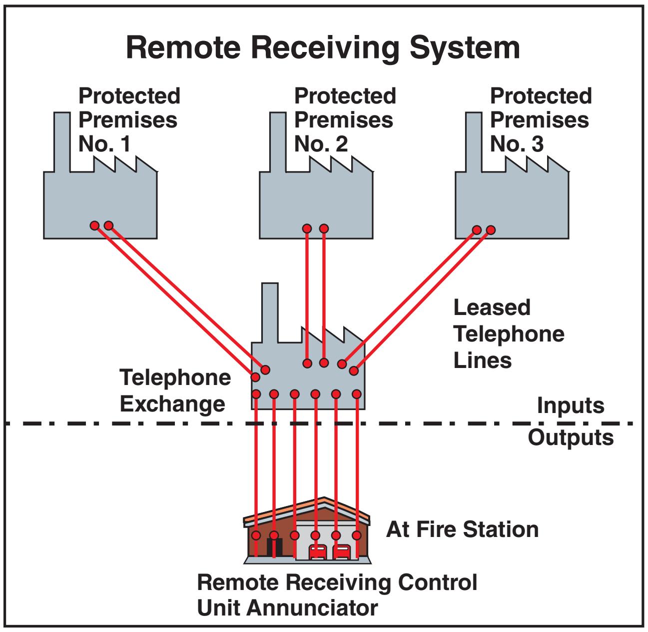


Figure 14.17 A remote receiver connects directly to the fire department dispatch center.

Public Emergency Alarm Reporting Systems

In some communities, fire alarm signals from a protected premises are transmitted directly to the fire department. Instead of being connected to the fire department telecommunications center through a municipal fire alarm box system, the **public emergency alarm reporting system** is connected by another means, usually a leased telephone line. Where permitted, a radio signal over a dedicated fire department radio frequency may also be used.

Public Emergency Alarm Reporting System — System that connects the protected property with the fire department alarm communications center by a municipal master fire alarm box or over a dedicated telephone line.

NOTE: For more information, see the IFSTA **Fire Protection, Detection, and Suppression Systems** manual.

A local energy system has its own power source and does not depend on the supply source that powers the entire municipal fire alarm system. In these systems, initiating devices can be activated even when the power supply to the municipal system is interrupted. However, interruption may result in the alarm only being sounded locally and not being transmitted to the fire department telecommunications center. The ability to transmit alarms during power interruptions depends on the design of the municipal system.

A shunt system is electrically connected to an integral part of the municipal fire alarm system and depends on the municipal system's source of electric power. When a power failure occurs in this type of system, an alarm indication is sent to the fire department communications center. NFPA® 72 allows only manual pull stations and waterflow detection devices to be used on shunt systems. Fire detection devices are not permitted on a shunt system.

Emergency Communications Systems

An emergency communications system is a supplementary system that may be provided in facilities in conjunction with detection and alarm signaling systems. The purpose of emergency communications systems is to provide a reliable communication system for occupants and firefighters. This system may either be a stand-alone system or it may be integrated directly into the overall fire detection and alarm-signaling system. System types include voice notification, two-way communication, and mass notification.

Voice Notification Systems

A one-way voice notification system warns building occupants that action is needed and tells them what action to take. This type is most commonly used in high-rise buildings, places of assembly, and educational occupancies. Occupants can be directed to move to areas of refuge in the building, leave the building, or stay where they are if they are in an unaffected area.

Two-Way Communication Systems

This system is most helpful to fire suppression personnel who are operating in a building, particularly in high-rise structures that interfere with portable radio transmissions. These two-way emergency communication systems use either intercom controls or special telephones **(Figure 14.18)**. Emergency phones are connected in the stairwells and other locations as required by the AHJ, NFPA® 72, or the adopted building code. These phones enable firefighters to communicate with the Incident Commander at the Fire Command Center. Most building codes require these systems in high-rise structures.

Other Emergency Communication Systems

The International Fire Code requires new and existing buildings to be provided with approved radio coverage for emergency responders. Radio coverage inside these buildings must be equivalent to the existing public safety communication capabilities outside the building. Fire department radio transmissions may be augmented by portable or fixed radio repeaters, bi-directional amplifiers, or a leaky coax. Radio repeaters operate by boosting or relaying fire department radio signals in buildings that may shield or disrupt normal high-frequency radio transmissions due to the weakness of these higher frequencies. Leaky coax systems are similar. Rather than boosting or relaying radio signals, these systems simply increase the transmitting capability in these building types by creating a more effective (virtual) antenna that can improve radio communications.

Mass Notification System (MNS) — System that notifies occupants of a dangerous situation and provides information and instructions.

Mass Notification Systems (MNS)

The purpose of a **mass notification system (MNS)** is to provide emergency communications to a large number of people on a wide-scale basis **(Figure 14.19)**. This communication can be directed to the occupants of a building or even an entire community. The events of September 11, 2001, as well as school shootings and other incidents, have provided evidence of the need for this type of system.

While the military was the first to implement this technology, today public and private facilities use it. Mass notification systems may be incorporated into an emergency communications system. Those individuals designing this type of system must take into consideration the building being protected as well as the needs of the occupants. When installed, mass notification systems may have a higher priority and override the fire alarm based on risk analysis. Specifications for mass notification systems are included in NFPA 72® and should be consulted for more information.

Figure 14.19 One-way voice communication systems are commonly used to provide occupants in a structure with instructions during an emergency.

Figure 14.18 An intercom or other two-way system may be used when it is necessary for occupants to respond to officials giving them instructions during an emergency.

Automatic Alarm-Initiating Devices

Automatic alarm-initiating devices, commonly called *detectors*, continuously monitor the atmosphere of a building, compartment, or area. When certain changes in the atmosphere are detected, such as a rapid rise in heat, the presence of smoke, or a flame signature, a signal is sent to the FACU. These signals originate a change-of-state condition like sprinkler water flow, the presence of smoke in a room or area, operation of a manual fire alarm box, or the loss of power to a fire pump.

Avoiding Nuisance Alarms

An inspector should remember that products of combustion may be present when there is no emergency condition. For example, flame detectors may activate if a welder strikes an arc in a monitored area, or smoke detectors may activate due to excessive moisture or atmospheric particles such as dust. These possibilities force fire protection system designers to take into account the normal activities that take place in any given protected area. They then must design a detection system that minimizes the chances of an accidental activation **(Figure 14.20)**.

Figure 14.20 Detection systems must take into account expected activities in order to minimize accidental activations.

The basic types of automatic initiating devices are those that detect heat, smoke, flame, and water flow. The two categories of heat detectors are fixed temperature and rate of rise. Devices that are a combination of these basic types are also available. The sections that follow describe the use of these devices:

- Fixed-temperature heat detectors
- Rate-of-rise heat detectors
- Smoke detectors
- Flame detectors
- Combination detectors
- Sprinkler waterflow alarm-initating devices

Figure 14.21 Heat detectors set to predetermined temperature ratings should be installed in ceilings in areas that are expected to accumulate heat.

Fixed-Temperature Heat Detectors

Fire detection systems using heat detection devices are among the oldest still in service. They are relatively inexpensive compared to other types of systems, and they are the least prone to nuisance alarms. They are, however, typically slower to activate under fire conditions than other types of detectors.

To be effective, heat detectors must be properly placed where heat is expected to accumulate (**Figure 14.21**). Heat detectors must also be selected at a temperature rating that will give at least a small margin of safety above the normal ceiling temperatures expected in a particular area. According to NFPA® 72, heat-sensing fire detectors must be color-coded and marked with their listed operating temperatures. See **Table 14.1** for a list of colors and temperatures for these detectors.

Because heat is a product of combustion, devices that use one of the following three primary principles of physics can detect the presence of heat:

1. Heat causes expansion of various materials.
2. Heat causes melting of certain materials.
3. Heated materials have thermoelectric properties that are detectable.

Table 14.1
Heat-Sensing Fire Detector Color Coding, Temperature Classification, and Temperature Rating

Color Coding	Temperature Classification	Temperature Rating °F	Temperature Rating °C
Uncolored	Low	100–134	39–57
Uncolored	Ordinary	135–174	58–79
White	Intermedite	175–249	80–121
Blue	High	250–324	122–162
Red	Extra High	325–399	163–204
Green	Very Extra High	400–499	205–259
Orange	Ultra High	500–575	260–302

All heat-detection devices operate on one or more of these principles. The various styles of fixed-temperature devices or detectors used in fire detection systems are addressed in the sections that follow.

Fusible Links/Frangible Bulbs

Although fusible links and frangible bulbs are usually associated with automatic suppression systems, they are also used in fire alarm systems. The operating principles of links and bulbs are the same in either type of system; only their application differs.

Fusible links are used to hold a spring device in the detector in the open position. When the melting point of the fusible link is reached, it melts and drops away. This action causes the spring to release and touch an electrical contact that completes a circuit and sends an alarm signal **(Figure 14.22)**. In order to restore the detector, the fusible link must be replaced.

A frangible bulb is also inserted into a detection device to hold two electrical contacts apart, much like that described for the fusible link. As the temperature increases, the liquid in the bulb expands **(Figure 14.23)**. The expanded liquid compresses the air bubble in the glass, and the bulb fractures and falls away. The contacts close to complete the circuit and send the alarm. In order to restore the detector, either the frangible bulb or the entire detector must be replaced.

Bimetallic Heat Detector

A bimetallic heat detector uses two types of metal with different heat-expansion ratios that are bonded. When subjected to heat, one metal expands faster than the other and causes the combined strip to arch. The amount the strip arches depends on the characteristics of the metals, amount of heat they are exposed to, and degree of arch present when in normal positions. All of these factors are calculated into the design of the detector.

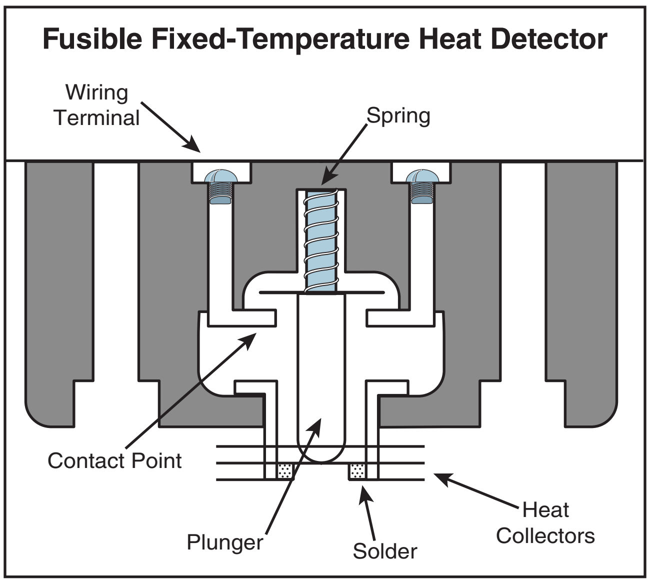


Figure 14.22 A fusible link is a fixed-temperature detector that uses solder with a known melting point to separate a spring from the contact points.

Figure 14.23 Frangible bulb detectors are designed to activate when the glass bulb breaks in response to heat.

A bimetallic strip may be positioned with one or both ends secured in the device. When positioned with both ends secured, a slight bow is placed in the strip. When heated, the expansion causes the bow to snap in the opposite direction. Depending on the design of the device, this action either opens or closes a set of electrical contacts that in turn sends a signal to the FACU **(Figure 14.24)**. Most bimetallic detectors are the automatic-resetting type. They need to be checked, however, to verify that they have not been damaged.

Continuous-Line Heat Detector

Most of the detectors described in this chapter are the spot style; that is, they detect conditions only at the spot where they are located. However, one style of heat detection device, the continuous-line device, can be used to detect conditions over a wide area.

Two models of continuous-line heat detectors are available: One model consists of a conductive metal inner core cable that is sheathed in stainless steel tubing **(Figure 14.25)**. The inner core and sheath are separated by an electrically insulating semiconductor material, which keeps the core and sheath from touching but allows a small amount of current to flow between them. The insulation is designed to lose some of its electrical-resistance capabilities at a predetermined temperature anywhere along the line. When the heat at any given point reaches the resistance-reduction point of the insulation, the amount of current transferred between the two components increases. This increase results in an alarm signal being sent to the FACU. This heat-detection device restores itself when the level of heat is reduced.

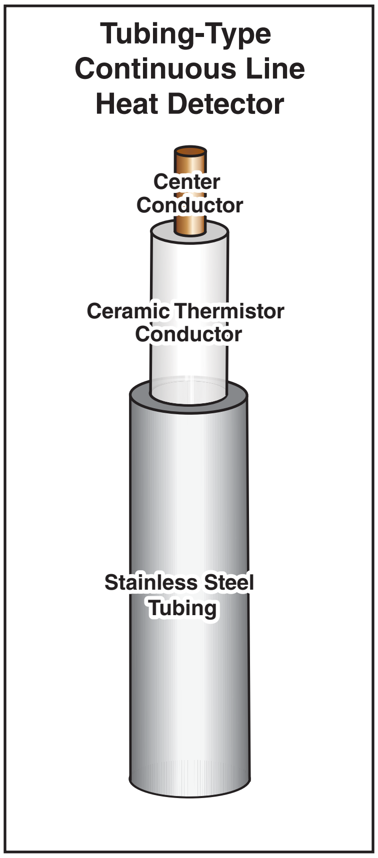


Figure 14.25 Continuous line detectors detect extreme temperatures at any point along the line of the cable.

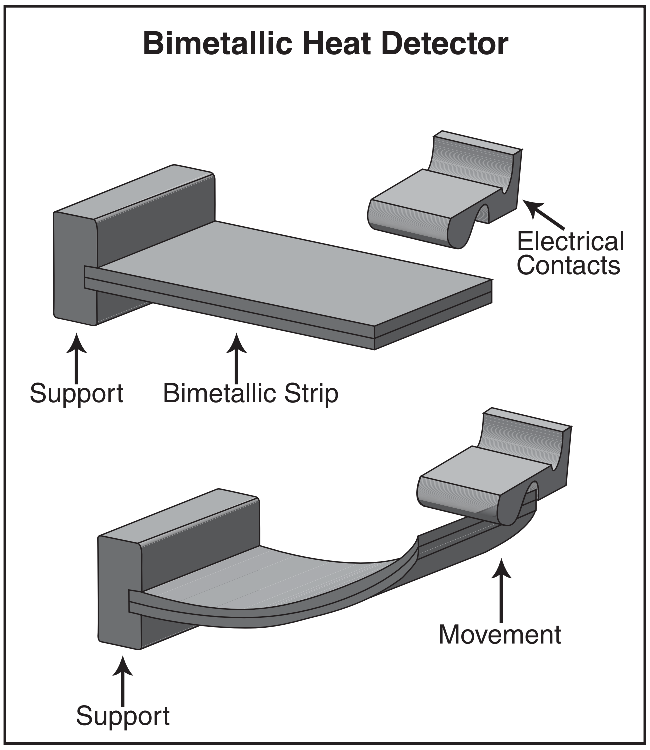


Figure 14.24 Heat causes the bimetallic strip to move and activate the alarm.

A second model of continuous-line heat-detection device uses two wires that are each insulated and bundled within an outer covering. When the melting temperature of each wire's insulation is reached, the insulation melts and allows the two wires to touch, which completes the circuit and sends an alarm signal to the FACU (**Figure 14.26**). To restore this continuous-line heat detector, the fused portion of the wires must be removed and replaced with new wire.

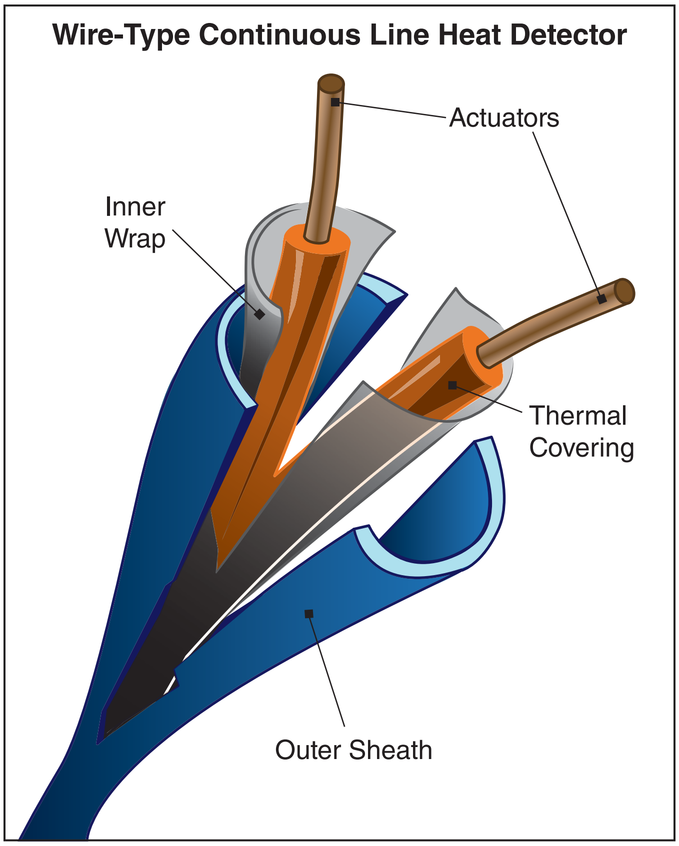


Figure 14.26 Heat causes the insulation on the wires to melt, allowing the wires to touch and complete the circuit.

Rate-of-Rise Heat Detectors

A rate-of-rise heat detector operates on the principle that fires rapidly increase the temperature in a given area. These detectors respond at substantially lower temperatures than fixed-temperature detectors. Typically, rate-of-rise heat detectors are designed to send a signal when the rise in temperature exceeds 12° to 15°F (7°C to 8°C) degrees per minute because temperature changes of this magnitude are not expected under normal, nonfire circumstances.

Most rate-of-rise heat detectors are reliable and not subject to nuisance activations. However, they can occasionally be activated under nonfire conditions. For example, if a rate-of rise detector is placed near a garage door in an air-conditioned building, an influx of summer air when the door opens will rapidly increase the temperature around the heat detector, causing it to activate. Avoiding such improper placement of a heat detector prevents nuisance activations.

All rate-of-rise heat detectors automatically reset. The following different styles of rate-of-rise heat detectors are currently in use:

- Pneumatic rate-of-rise line heat detector
- Pneumatic rate-of-rise spot heat detector
- Rate-compensation heat detector
- Electronic spot-type heat detector

Pneumatic Rate-of-Rise Line Heat Detector

A pneumatic rate-of-rise line heat detector can monitor large areas of a building. Line heat detectors consist of a system of metal pneumatic tubing arranged over a wide area of coverage (**Figure 14.27, p. 628**).

The space inside the tubing acts as a pressurized air chamber that allows the contained air to expand as it heats. These heat detectors contain a flexible diaphragm that responds to the increase in pressure from the tubing. When an area being served by the tubing experiences a temperature increase, the air pressure increases and the heat-detection device operates.

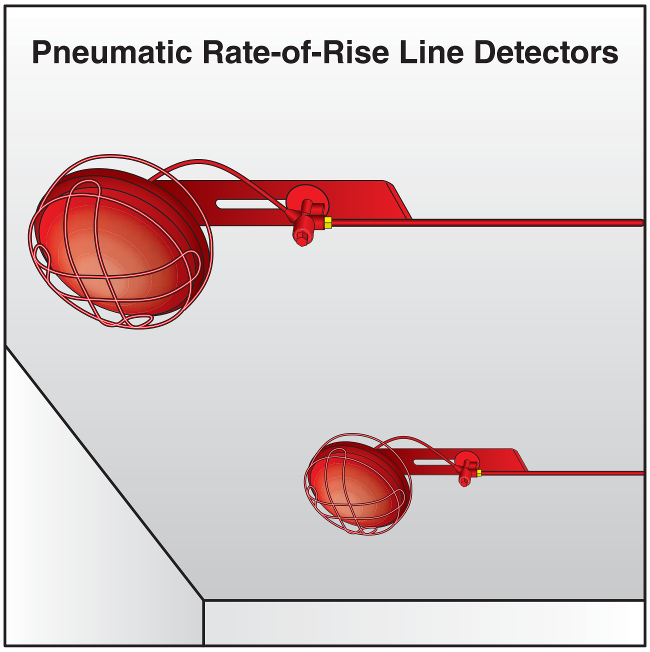


Figure 14.27 Line heat detectors used in pneumatic rate-of-rise systems depend on the change in temperature and increase in pressure of the air in the tubing to activate the alarm system.

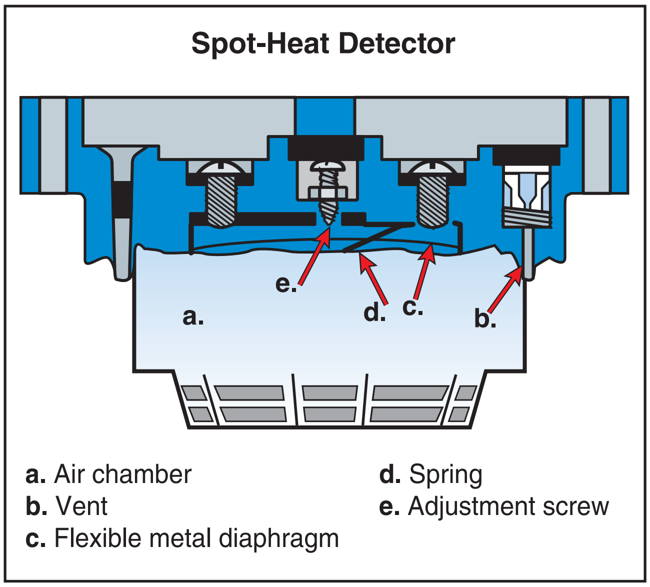


Figure 14.28 A spot detector monitors a specific location and sends a signal to the alarm panel.

Pneumatic Rate-of-Rise Spot Heat Detector

A rate-of-rise spot heat detector operates on the same principle as the pneumatic rate-of-rise line heat detector. The major difference between the two is that the spot heat detector is self-contained in one unit that monitors a specific location **(Figure 14.28)**. Alarm wiring extends from the detector back to the FACU.

Rate-Compensation Heat Detector

This heat detector is designed for use in areas that are subject to regular temperature changes, but at rates that are slower than those of fire conditions. Rate-compensation heat detectors contain an outer bimetallic sleeve with a moderate expansion rate. This outer sleeve contains two bowed struts that have a slower expansion rate than the sleeve. The bowed struts have electrical contacts. In the normal position, these contacts do not touch. When the detector is heated rapidly, the outer sleeve expands lengthwise. This expansion reduces the tension on the inner strips and allows the contacts to meet, thus sending an alarm signal to the FACU.

If the rate of temperature rise is fairly slow, such as 5°F to 6°F (2°C to 3°C) per minute, the sleeve expands at a slow rate that maintains tension on the inner strips. This tension prevents unnecessary system activations.

Thermistor — Semiconductor made of substances whose resistance varies rapidly and predictably with temperature.

Electronic Spot-Type Heat Detector

An electronic spot-type heat detector consists of one or more **thermistors** that produce a marked change in electrical resistance when exposed to heat. The rate at which thermistors are heated determines the amount of current that is generated **(Figure 14.29)**. Greater changes in temperature result in larger amounts of current flowing and activation of the alarm system.

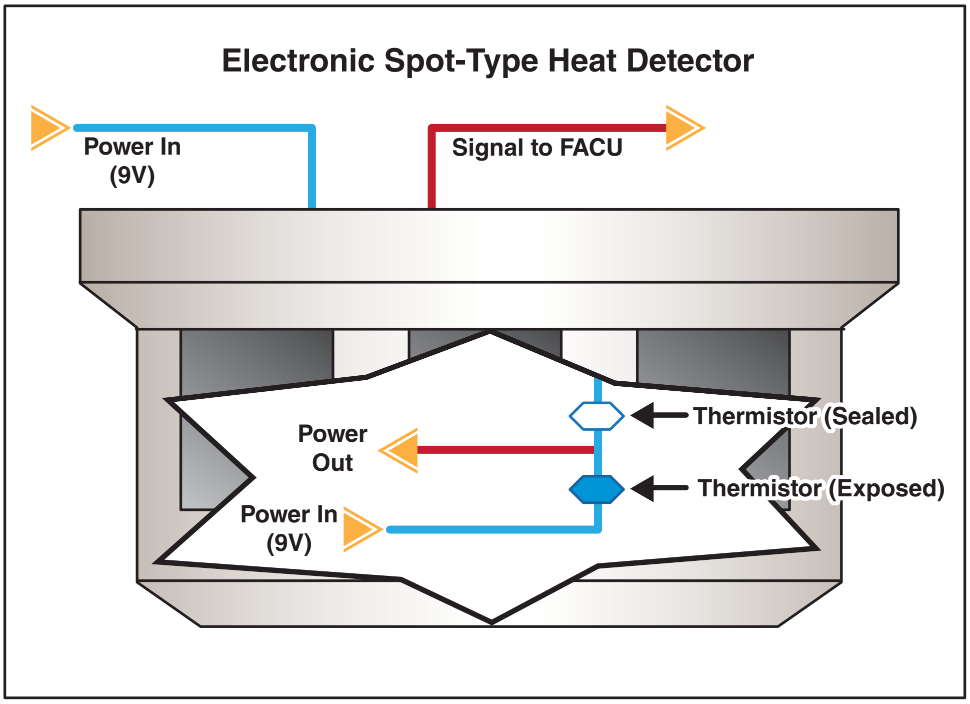


Figure 14.29 The rate at which the temperature of the internal thermistors increases determines the amount of current that is generated to activate an alarm signal.

These heat detectors can be calibrated to function as rate-of-rise (approximately 15°F [8°C] per minute) detectors and function at a fixed temperature. Heat detectors of this type are designed to bleed or dissipate small amounts of current, which reduces the chance of a small temperature change activating an alarm.

Smoke Detectors

Smoke detectors serve the purpose of early detection, notification, and reaction. Some detectors are also used to activate mechanical or electrical systems, such as dampers, doors, and electronic shutdown. Smoke detectors have evolved into two principal types of devices:

- A detector that provides early detection and reports back to an alarm panel to initiate evacuation alarms
- A detector that provides some type of signal to initiate one of the actions discussed above.

Smoke Detector — Alarm-initiating device designed to actuate when visible or invisible products of combustion (other than fire gases) are present in the room or space where the unit is installed.

Smoke Alarms vs. Smoke Detectors

The terms *smoke alarm* and *smoke detector* are often used interchangeably. While this is common practice, it is technically incorrect. Smoke alarms are the devices typically installed in residential occupancies. These devices combine a smoke detector with a local notification appliance. When activated, smoke alarms emit an audible alarm to notify occupants of the presence of smoke.

Smoke detectors differ from smoke alarms in that they do not include a local notification appliance. When activated, smoke detectors send a signal to an FACU or a similar device. The FACU then initiates the alarm to notify occupants.

Smoke detection is the preferred automatic alarm device in such occupancy types as residences and health and institutional care facilities because smoke detectors sense the presence of a fire much more quickly than heat-detection devices. Because of the dangers of toxic fire gases, an early warning can mean the difference between a safe escape and no escape at all.

Many factors affect the performance of smoke detectors, including:

- Type and amount of combustibles
- Rate of fire growth
- Proximity of the detector to the fire
- Ventilation within the area involved

Smoke detectors and smoke alarms are tested, certified, and listed based on their performance by third-party testing services. Regardless of their principle of operation, all smoke detectors are required to respond to the same fire tests. Two basic methods of smoke detection are in use: photoelectric and ionization. The allowable sensitivity ranges for both types of smoke detectors are established by UL. The following sections also describe duct and video-based detectors.

Photoelectric Smoke Detector — Type of smoke detector that uses a small light source, either an incandescent bulb or a light-emitting diode (LED), to detect smoke by shining light through the detector's chamber: smoke particles reflect the light into a light-sensitive device called a photocell.

Photoelectric Smoke Detectors

Photoelectric smoke detection works on all types of fires and usually responds more quickly to smoldering fires than ionization smoke detection. Photoelectric smoke detection is best suited for areas containing overstuffed furniture and other areas where smoldering fires can occur.

A photoelectric device consists of a photoelectric cell coupled with a specific light source. The photoelectric cell functions in one of two ways to detect smoke: projected-beam application (obscuration) or refractory application (scattered).

The projected-beam application style of photoelectric detector uses a beam of light focused across the area being monitored onto a photoelectric-receiving device such as a photodiode. The cell constantly converts the beam into current, which keeps a switch open. When smoke interferes with or obscures the light beam, the amount of current produced is lessened. The detector's circuitry senses the change in current, and initiates an alarm when a current change threshold is crossed **(Figure 14.30)**.

Projected-beam application smoke detectors are particularly useful in buildings where a large area of coverage is desired, such as in churches, atriums, or warehouses. Rather than wait for smoke particles to collect at the top of an open area and sound an alarm, the projected-beam application smoke detector is strategically positioned to sound an alarm more quickly.

Projected-beam application smoke detectors need to be mounted on a stable stationary surface. Any movement due to temperature variations, structural movement, and vibrations can cause the light beams to misalign.

A refractory application photoelectric smoke detector uses a beam of light from a light-emitting diode (LED) that passes through a small chamber at a point distant from the light source. Normally, the light does not strike the photocell or photodiode. When smoke particles enter the light beam, light strikes the particles and reflects in random directions onto the photosensitive device, causing the detector to generate an alarm signal **(Figure 14.31)**.

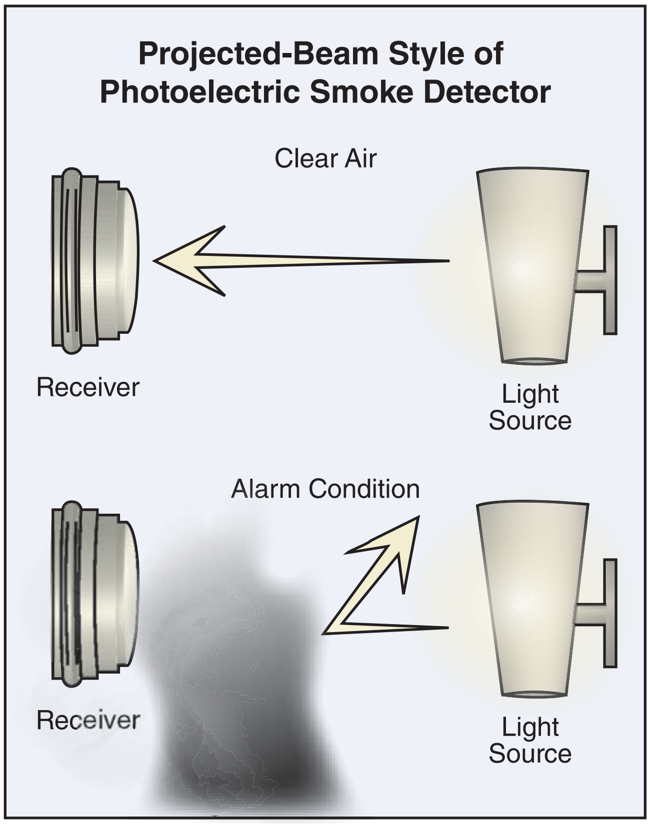


Figure 14.30 A projected-beam photoelectric detector activates when light is blocked by smoke from reaching a sensor.

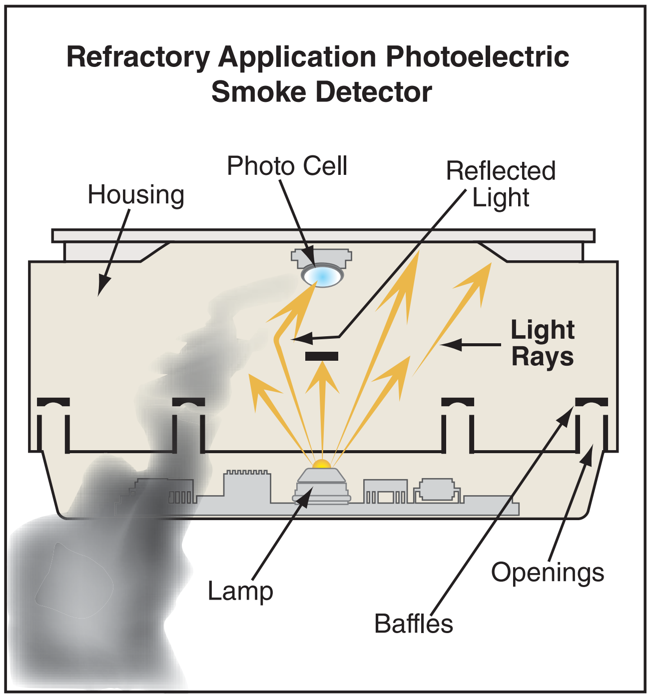


Figure 14.31 A refractory photoelectric smoke sends an alarm when light reaches a sensor after reflecting off smoke.

Ionization Smoke Detector — Type of smoke detector that uses a small amount of radioactive material to make the air within a sensing chamber conduct electricity.

Ionization Smoke Detectors

An **ionization smoke detector** contains a sensing chamber consisting of two electrically charged plates (one positive and one negative) and a radioactive source for ionizing the air between the plates. A small amount of Americium 241 that is adjacent to the opening of the chamber ionizes the air particles as they enter. The ionized particles free electrons from the negative electron plate and the electrons travel to the positive plate. Thus, a small ionization current measurable by electronic circuitry flows between the two plates.

Products of combustion, which are much larger than the ionized air molecules, enter the chamber and collide with the ionized air molecules. As the two interact, they combine and the total number of ionized particles is reduced. This action results in a decrease in the chamber current between the plates. When a predetermined threshold current is crossed, an alarm is initiated (**Figure 14.32**).

Changes in humidity and atmospheric pressure in the room can cause an ionization detector to malfunction and initiate a nuisance alarm. To compensate for the possible effects of humidity and pressure changes,

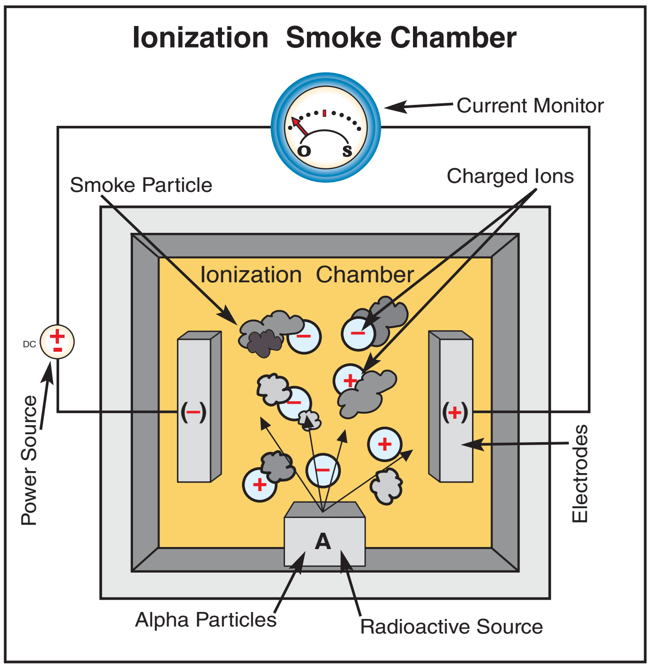


Figure 14.32 An ionization smoke detector monitors charged particles inside the detector.

a dual-chamber ionization detector that uses two ionization chambers has been developed and may be found in many jurisdictions. One chamber senses particulate matter, humidity, and atmospheric pressure. The other chamber is a reference chamber that is partially closed to outside air and affected only by humidity and atmospheric pressure. Both chambers are monitored electronically and their outputs are compared.

When the humidity or atmospheric pressure changes, both chambers respond equally to the change, but remain balanced. When particles of combustion enter the sensing chamber, its current decreases while the reference chamber remains unchanged. The imbalance in current is detected electronically and an alarm is initiated.

An ionization smoke detector works satisfactorily on all types of fires, although it generally responds more quickly to flaming fires than photoelectric smoke detectors. The ionization detector is an automatic resetting type and is best suited for rooms that contain highly combustible materials, such as the following:

- Cooking fat/grease
- Flammable liquids
- Newspapers
- Paint
- Cleaning solutions

An air-sampling smoke detector is a type of ionization detector that is designed to continuously monitor a small amount of air from the protected area for the presence of smoke particles. There are two basic types of air-sampling smoke detectors. The most common one is the cloud-chamber type **(Figure 14.33)**. This detector uses a small air pump to draw sample air into a high-humidity chamber within the detector. The detector then imparts the high humidity to the sample and lowers the pressure in the test chamber. Moisture condenses on any smoke particles in the test chamber, which creates a cloud inside the chamber. The detector triggers an alarm signal when the density of this cloud exceeds a predetermined level.

The second type of air-sampling smoke detector is composed of a system of pipes spread over the ceiling of the protected area **(Figure 14.34)**. A fan in the detector/controller unit draws air from the building through the pipes. The air is then sampled using a photoelectric sensor.

Duct Smoke Detectors

Duct smoke detectors are installed in the return or supply ducts or plenums of HVAC systems to prevent smoke and products of combustion from being spread throughout the building. Duct smoke detectors are specifically listed for installation within higher air velocities. Upon the detection of smoke, the HVAC system will either shut down or transition into a smoke-control mode. The detection of smoke in duct areas is sometimes difficult because the smoke can be diluted by the return air from other spaces or outside air. Duct smoke detectors are no substitute for other types of smoke detectors in open areas.

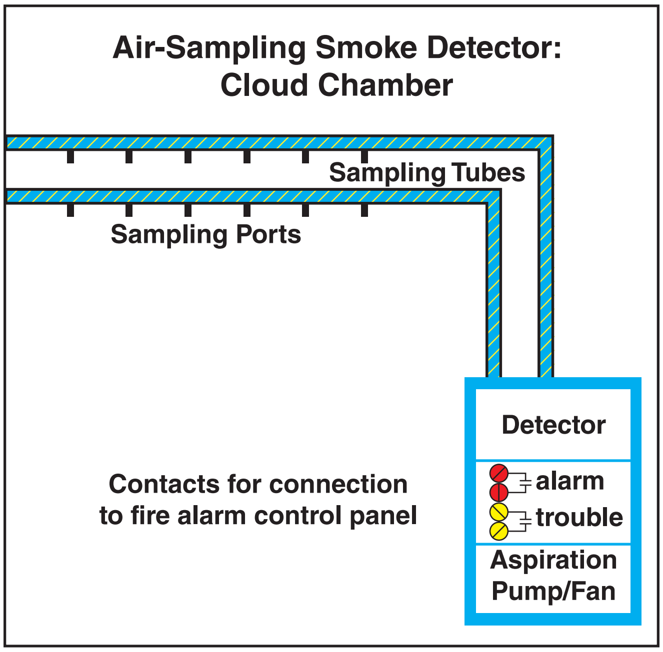


Figure 14.33 An aspiration pump draws samples of air into the air-sampling smoke detector, which activates when it detects smoke or other particles of combustion.

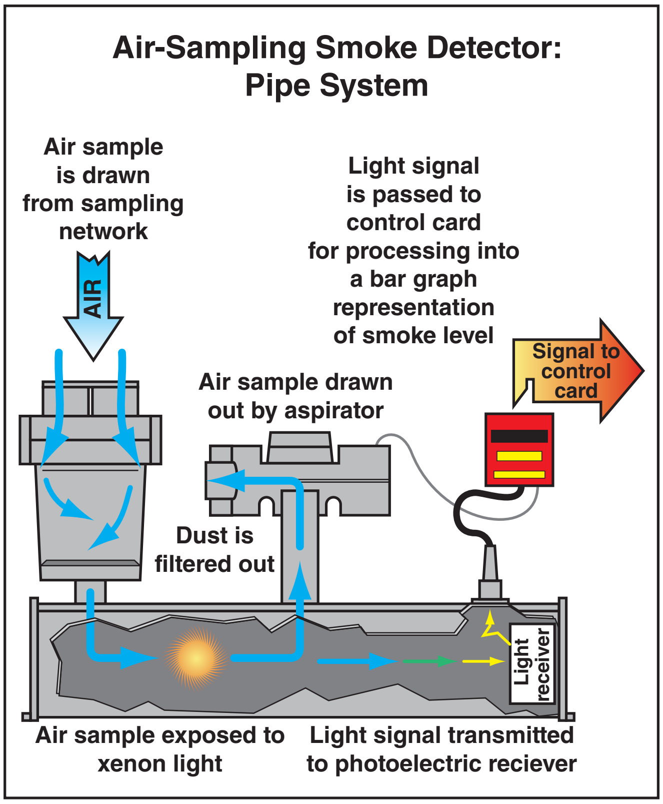


Figure 14.34 A similar type of air-sampling smoke detector uses pipes to draw air into the system. Activation depends on a photoelectric cell.

Video-Based Detectors

Video-based smoke and flame detection operates on the principle of detecting changes in a digital video image from a camera or a series of cameras. Images are transmitted from a closed-circuit television to a computer that looks for changes in the images. These cameras will work only in a lighted space. They also provide an image to an operator who is monitoring the system. These systems offer advantages in large, open facilities where there may be a delay in smoke movement and detection.

Flame Detectors

A flame detector is sometimes called a light detector. There are three basic types:

- Those that detect light in the ultraviolet wave spectrum (UV detectors) **(Figure 14.35, p. 634)**
- Those that detect light in the infrared wave spectrum (IR detectors) **(Figure 14.36, p. 634)**
- Those that detect light in both UV and IR waves

An infrared detector is effective in monitoring large areas, such as an aircraft hangar or computer room. While these types of detectors are among the fastest to respond to fires, they are also easily activated by such nonfire conditions as welding, sunlight, and other bright light sources. They must only be placed in areas where these triggers can be avoided or limited. They must also be positioned so that they have an unobstructed view of the protected area. If they are blocked, they cannot activate.

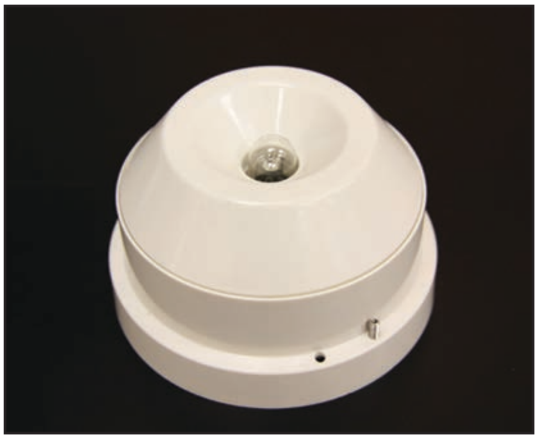


Figure 14.35 A UV flame detector detects light in the untraviolet wave spectrum.

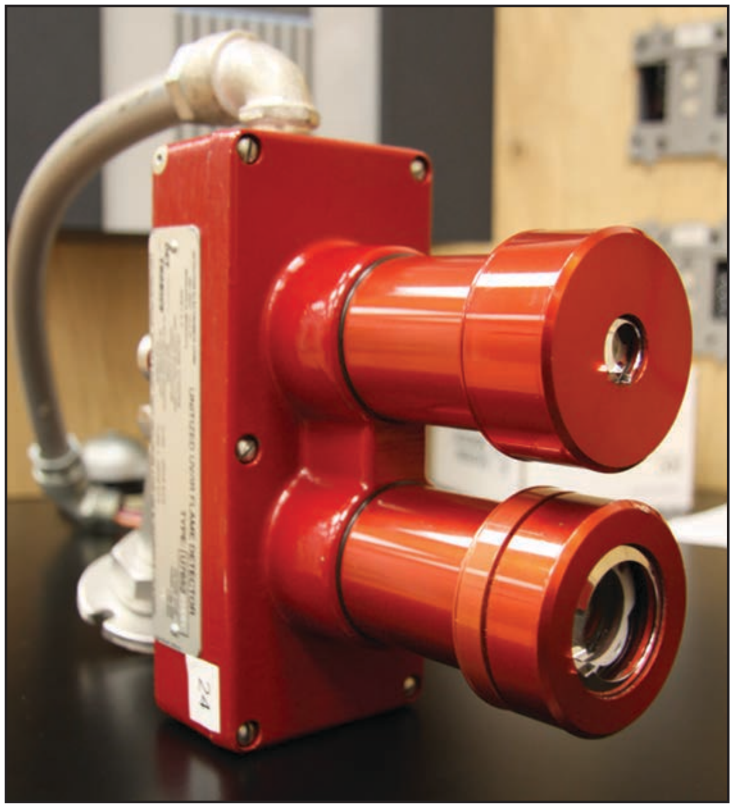


Figure 14.36 Infrared flame detectors are effective for monitoring large area structures.

To prevent accidental activation, an infrared detector requires the flickering action of a flame before it activates to send an alarm. This detector is typically designed to respond to 1 square foot (0.09 m^2) of fire from a distance of 50 feet (15 m).

There are also video-based flame detectors that work on the same principle as the video-based smoke detectors. The images from the closed-circuit televisions are sent to a computer with software designed to detect the characteristics of a flame. This type of flame detection system is used in certain chemical or petroleum facilities.

Combination Detectors

Depending on the design of the system, various combinations of the previously described detection devices may be used in a single device. These combinations include fixed-rate/rate-of-rise detectors, heat/smoke detectors, and smoke/fire-gas detectors (**Figure 14.37**). These combinations give the detector the benefit of both services and increase their responsiveness to fire conditions.

Sprinkler Waterflow Alarm-Initating Devices

An automatic initiating device is designed to activate an audible alarm (horn/strobe) when water begins to flow through the sprinkler system **(Figure 14.38)**. The notification appliance is usually located on the exterior of the building near the sprinkler riser. In addition, many alarm systems are connected to fire alarm systems that monitor fire sprinkler water flow through the use of electronic flow switches that notify the FACU when water is flowing through the system. This action may, in turn, cause the notification and signaling devices to function.

Figure 14.37 A combination heat/smoke detector.

Figure 14.38 A waterflow alarm indicates the flow of water through the system, and may be accompanied by a system drain valve.

Manually Actuated Alarm-Initiating Devices

Manually actuated fire alarm boxes, commonly called manual pull stations, allow occupants to manually initiate the fire alarm signaling system. Manual pull stations may be connected to systems that sound local alarms, off-premise alarm signals, or both.

Although manual pull stations come in a variety of shapes and sizes, they are usually red in color with white lettering that specifies what they are and how they are to be used **(Figures 14.39 a-c)**. The manual pull station should only be used for fire-signaling purposes unless it is designed for other uses or to activate a fixed fire suppression system.

Figures 14.39 a-c Manually operated alarm-initiating devices may look slightly different, but all are important tools for signaling emergencies.

According to NFPA® 72, the pull station should be mounted on walls or columns so that the operable part is not less than 42 inches and not more than 48 inches above the floor. The manual pull station should be positioned so that it is in plain sight and unobstructed. Multistory facilities should have at least one pull station on each floor. In all cases, travel distances to the manual pull station should not exceed 200 feet (60 m).

Manual pull stations can be single-action or double-action, which are described as follows:

- **Single-action** — Operates after a single motion is made by the user. When the station lever is pulled, a lever or other movable part is moved into the alarm position and a corresponding signal is sent to the FACU (**Figure 14.40**).
- **Double-action** — Requires the operator to perform two steps to initiate an alarm. First, the operator must lift a cover or open a door to access the alarm control **(Figure 14.41)**. Then the operator must manipulate an alarm lever, switch, or button to send the signal to the fire alarm control panel. Double-action manual pull stations may be confusing to certain occupant/operators due to the need to perform two separate steps before an alarm is initiated.

A manual pull station may be protected by a listed protective cover in areas where it would be subject to damage or accidental activation (**Figure 14.42**). These protective devices are used in gymnasiums, materials handling areas, or in other locations where accidental activation is possible. Listed protective covers can only be installed over single-action manual pull stations.

Figure 14.40 Single-action pull stations require only a single motion to trigger an alarm.

Figure 14.41 A double-action pull station has a panel that must be lifted so the operator can access and operate the pull station.

Figure 14.42 A manual alarm may require a cover to prevent damage. *Courtesy of Rich Mahaney.*

Manual pull stations that require the operator to break a small piece of glass with a mallet are no longer recommended. These devices were designed to discourage false alarms and were somewhat effective for that purpose. However, broken glass presents an injury hazard to the operator at a time when an untrained operator is least capable of clear thinking. Polycarbonate covers have taken the place of glass; however, these older types of pull stations may still be found in many old structures. Some pull stations leave a dye or ultraviolet residue on the activator that will transfer to the fingers of someone pulling the alarm to discourage malicious false alarms.

Inspection and Testing

To verify operational readiness and proper performance, fire detection and alarm signaling systems must be tested when they are installed and again on a continuing basis. Periodic testing is often referred to as a **service test**. Inspectors should be familiar with the service testing and inspection requirements for detection and alarm systems.

Service Test — Series of tests performed on fire protection, detection, and/or suppression systems in order to verify operational readiness. These tests should be performed at least yearly or whenever the system has undergone extensive repair or modification.

During inspections, an inspector should note the functional aspects of the fire detection and alarm systems. An inspector should be able to recognize physical and environmental conditions that may negatively affect system operation or even render the system inoperative. An inspector should also recognize conditions that may trigger an unwanted alarm and recommend corrective action to reduce or eliminate the number of fire department responses to possible nuisance alarms.

Inspectors who routinely conduct inspections need to have a working knowledge of these systems. Inspectors are generally limited to visual inspections and supervision of system tests **(Figure 14.43)**. Often they will not have the authority or responsibility for operating or maintaining these systems. In most cases, representatives of the owner/occupant or alarm system contractors perform system tests and maintenance. These individuals should be qualified and experienced in the various types of devices and systems. Some general inspection considerations for a fire inspector include the following:

Figure 14.43 Fire department personnel who conduct inspections must have a working knowledge of detection and alarm systems.

- Check for changes to the building or use of rooms that may result in different requirements for detection systems, audio/visual alarms, or that cause a coverage issue.
- Verify that all equipment, especially initiating and signaling devices, are free of dust, dirt, paint, and other foreign materials.
- Verify that manual pull stations, audible or visual warning devices, and any other components are not blocked or obstructed in any way.
- Verify that the monitoring system is operational, if applicable.

Fire detection and alarm systems must be tested and inspected regularly if the systems are to work reliably during an emergency. The actual performance of the tests is the responsibility of the owner/occupant or the fire alarm monitoring company. Locally adopted fire codes usually mandate that inspectors witness system tests. Periodic tests and inspections are performed on all components of the fire detection and alarm systems.

NOTE: Testing and inspection intervals may vary in accordance with local codes and ordinances.

Because it is time-consuming to test fire alarm systems in a jurisdiction, it is not always possible for fire department or inspection personnel to witness every test. Most of the time, occupants have to test the systems on their own and document the results. Inspectors should review the inspection/testing carried out by qualified third parties. The inspector should review the documentation for any deficiencies found or repairs needed, and orders sent for correction of deficiencies.

Inspectors must be familiar with their jurisdiction's inspection procedures. The following sections will provide more detail into inspecting and testing various alarm system components and types of alarm signaling systems.

Inspection Considerations for Fire Alarm Control Units

Inspectors should check the FACU to verify that all parts are operating properly. All switches should perform their intended functions and all indicators should light or sound when tested (**Figure 11.44**). When individual detectors are triggered, the FACU should indicate the proper location and warning lamps should light. Remember that the indicated location could very well be out of date due to renovations.

Verify that access to FACUs, recording instruments, and other devices are not obstructed and do not have objects stored on, in, or around them. Many FACUs have storage areas with locking doors for extra relays, light bulbs, and test equipment. Store items somewhere else if the unit does not have a storage area designed into it. Otherwise, they may foul moving parts or cause electrical shorts that can result in system failure.

Figure 14.44 Inspectors must verify that all the switches and detector lights on annunciator panels work when tested.

Auxiliary devices can also be checked at this time. The auxiliary devices include the following: local evacuation alarms and HVAC functions, such as air-handling system shutdown controls, and fire dampers. All devices must be restored to proper operation after testing.

The receiving signals should also be checked during this time. The proper signal and/or number of signals should be received and recorded. Signal impulses should be definite, clear, and evenly spaced to identify each coded signal. There should be no sticking, binding, or other irregularities.

At least one complete round of printed signals should be clearly visible and unobstructed by the receiver at the end of the test. The time stamp should clearly indicate the time of the signal and should not interfere in any way with the recording device.

Inspection Considerations for Alarm-Initiating Devices

Any fire detection and alarm-signaling system will be ineffective unless the alarm-initiating devices are in proper working order and send the appropriate signal to the system control unit. Inspectors may wish to witness the activation of selected devices to verify that the device and the system are operational.

Automatic alarm-initiating devices should be checked after installation, after a fire, and at scheduled times based on guidelines established by the AHJ or the manufacturer. Often these guidelines are found in the locally adopted fire code. All detector testing should be in accordance with local guidelines, manufacturer's specifications, and NFPA® 72.

Periodic testing procedures are included in NFPA® 72 and in the fire alarm manufacturer's literature for the system and its components. The following periodic tests are recommended test procedures for the listed device:

- **Restorable heat detection device** — Test one detector on each signal circuit semiannually. A different detector should be selected each time and so noted on the inspection report. Subsequent inspections should include a copy of the previous report so that the same detector is not tested each time.

Restorable heat detectors should be checked by following approved testing procedures described by the manufacturer . Hair dryers or electric heat guns can be used to test restorable heat detectors. Nonrestorable heat detectors must not be tested during field inspections.

Remember that some combination detectors have both restorable and nonrestorable elements. Exercise caution to avoid tripping the nonrestorable element. Nonrestorable pneumatic detectors should be tested mechanically. Those detectors equipped with replaceable fusible links should have the links removed to see whether the contacts touch and send an alarm signal. The links can then be replaced.

- **Fusible-link detector with replaceable links** — Check semiannually by removing the link and observing whether or not the contacts close. After the test, the fusible link must be reinstalled. It is recommended that the links be replaced at 5-year intervals.
- **Pneumatic detector** — Test semiannually with a heating device or a pressure pump. If a pressure pump is used, the manufacturer's instructions must be followed.

- **Smoke detector** — Test semiannually in accordance with the manufacturer's recommendations. The instruments required for performance and sensitivity testing are usually provided by the manufacturer. Sensitivity testing should be performed after the detector's first year of service and every two years after that.
- **Flame and gas detection devices** — Require testing by highly trained individuals because they are very complicated devices. Testing is typically performed by professional alarm service technicians on a contract basis.

Figure 14.45 It is important to use approved testing procedures for smoke heat detectors.

NOTE: Inspectors are only responsible for witnessing the tests, not performing them.

The manufacturers of smoke and flame detectors usually have specific instructions for testing their detectors. These instructions must be followed on both the acceptance and service tests. They may include the use of smoke-generating devices, aerosol sprays, or magnets **(Figure 11.45)**. Using nonapproved testing devices may result in the manufacturer's warranty being voided.

For manual alarm-initiating devices, check the following:

- Verify that access to the device is unobstructed.
- Observe that each unit is easy to operate.

Regardless of the type of detector in use, detectors found in the following conditions should be replaced or sent to a recognized testing laboratory for testing:

- Restored to service after a period of disuse
- Obviously corroded
- Painted even if attempts were made to clean them
- Mechanically damaged or abused
- Subjected to current surges, overvoltages, or lightning strikes
- Subjected to foreign substances that might affect their operation
- Subjected to direct flame, excessive heat, or smoke damage

A permanent record of all detector tests must be maintained for at least 5 years. The following minimum information should be included in the record:

- Test date **(Figure 14.46)**
- Detector type
- Location
- Type of test
- Test results

A nonrestorable fixed-temperature detector cannot be tested periodically. Testing would destroy the detector and require the system to be rendered inoperable until a replacement detector can be located and installed. For this reason, tests are not required until 15 years after the detector has been installed.

Figure 14.46 Check that inspection records are up-to-date.

At that time, two percent of the detectors must be removed and laboratory tested. If a failure occurs in one of the detectors, additional detectors must be removed and laboratory tested. These tests are designed to determine if there is a problem with failure of the product in general or a localized failure involving just one or two detectors.

Inspection Considerations for Alarm Signaling Systems

The following list gives a brief synopsis of the inspection and testing requirements for various types of systems and timetable guidelines. If any of these systems use backup electrical generators for emergency power, those generators should be run under load monthly for at least 30 minutes.

- **Local alarm systems** — Test in accordance with guidelines established in NFPA® 72 and the manufacturer's recommendations.
- **Central station systems** — Test signaling equipment on a monthly basis. Check waterflow indicators, automatic fire detection systems, and supervisory equipment bimonthly. Check manual fire alarm devices, water tank level devices, and other automatic sprinkler system supervisory devices semiannually. In scheduling these tests, both facility/building supervisory personnel and central station personnel must be notified before the test to prevent them from evacuating occupants or dispatching fire units.
- **Auxiliary fire alarm systems** — The occupant should visually inspect and actively test these systems monthly to verify that all parts are in working order and the operation of the system results in a signal being sent to the fire department telecommunications center. Test noncoded manual fire alarm boxes semiannually.
- **Remote station and proprietary systems** — Test according to the testing requirements established by the AHJ. Test fire detection components of these systems monthly. Test water-flow indicators semiannually; however, the frequency of testing may depend upon the type of indicator.

- **Emergency voice/alarm systems** — Conduct functional test of the various components in these systems quarterly (by the owner/occupant). Include selected parts of the system that are likely to be used during an incident. Check all components at least annually.

NOTE: In all cases of testing and inspection frequencies, check with the most current edition of NFPA® 72.

II

Inspecting, Testing, and Evaluating Fire Detection and Alarm Systems

An Inspector II must be familiar with the service testing and inspection requirements for detection and alarm systems, initiating devices, and FACUs, along with operation of fire detection and alarm systems and the building code requirements for their installation, testing, and monitoring. During plan reviews for new buildings, an inspector may be required to evaluate and approve the design of fire detection and alarm systems.

Detection devices were covered earlier in this chapter for Fire Inspector I. This portion of the chapter will deal in greater detail with acceptance tests and occupant notification devices typically found in a modern fire detection and alarm system.

Acceptance Test — Preservice test on fire protection, detection, and/or suppression systems after installation to ensure that the system operates as intended.

Acceptance Testing

Acceptance testing is performed soon after the system has been installed and prior to occupancy to ensure it meets design criteria and functions properly. Representatives of the building owner/occupant, the fire department, and the system installer/manufacturer should witness acceptance tests. The fire department representative may be a fire inspector, a staff fire protection engineer, or in some cases the fire marshal.

Some jurisdictions require a record of completion from the system installer/manufacturer demonstrating that the system has been thoroughly tested before the fire department inspection. This record prevents the inspector from checking a system that may not have been properly installed. **See Appendix E** for a commercial fire alarm acceptance test checklist.

Activities during an acceptance test include the inspector witnessing the following:

- Inspect all wiring for proper support.
- Look for wear, damage, or any other defects that may render the insulation ineffective.
- Inspect conduit for solid connections and proper support wherever circuits are enclosed in conduit.
- Check batteries that are used as an emergency power source for clean contacts and proper charge. Immediately replace batteries that fail inspection and testing procedures. Many batteries have floating-ball indicators that show whether they are properly charged.

All of the following functions of the fire detection and alarm-signaling system should be operated during the acceptance tests:

- **Alarm, supervisory, and trouble signals** — Check actual wiring and circuitry against the system drawing to verify that all are connected properly **(Figure 11.47)**.
- **Fire alarm control unit (FACU)** — Operate all interactive controls at the FACU to verify that they control the system as designed. Inspect thoroughly to verify that the FACU is in proper working order.
- **Alarm-initiating and occupant notification devices and circuits** — Check all items for proper operation. Test pull stations, detectors, bells, and strobe lights to verify that they are operational. Test each initiating device to note that it sends an appropriate signal and causes the system to send the prescribed alarm, supervisory or trouble signal as prescribed on the approved plans.
- **Power supplies** — Operate the system on both the primary and secondary power supplies to verify that both will supply the system adequately **(Figure 11.48)**.

Check the ability of supervising station services to respond to an alarm. The alarm-receiving capability and response of those involved must be verified, and a telecommunications facility must receive the request for emergency service.

The results of all tests must be documented to the satisfaction of the AHJ. Only after all parts of the system have successfully passed the tests should a system certification be issued. Issuing the alarm system certificate is typically a preliminary step toward the issuance of a certificate of occupancy. NFPA® 72 contains complete information on system acceptance tests.

Occupant Notification Devices

The locally adopted building code, other governing code or standard, or system installation standard will determine the system requirements for occupant notification. Generally, notification is the activation of horns, bells, and strobes that are used in the occupancy to alert occupants of a fire. Notification may

Figure 14.47 Verify that the circuitry and wiring match the system drawing.

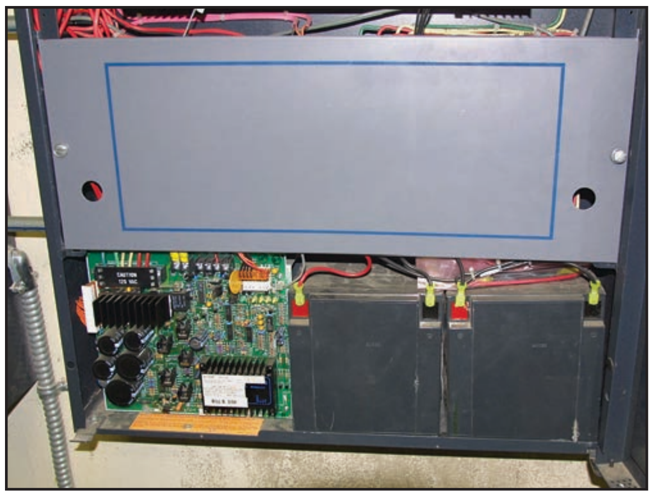


Figure 14.48 The alarm system must contain a storage battery and charger.

Figure 14.49 Verify that occupant notification devices are consistent with the requirements of the locally adopted code. *Courtesy of Rich Mahaney.*

Figure 14.50 A recessed voice evacuation system. *Courtesy of Rich Mahaney.*

also include voice evacuation systems, alarm printers, annunciators, textual displays, and graphic displays that are included as a part of the installed system **(Figure 14.49)**.

The local building code usually dictates the installation of voice evacuation systems based on the size and type of occupancy. NFPA® 72 dictates where and how these devices are installed **(Figure 14.50)**. The locally adopted building and fire codes typically specify requirements for the annunciators and graphic displays. Often, the graphic displays are located near the front entrance to the building and provide a complete view of the building with alarm zones and detection points. In some installations, remote annunciators will be located near the entrance where the emergency responders will enter the building.

Almost all fire detection and alarm system installations require the use of audible signals through horns, bells, or chimes. Building code requirements for disability access will require visual occupant notification appliances. Visual alarm indicators are accomplished through the use of flashing strobe lights. In some instances, a rotating beacon may also be used for outdoor installation, or for warning on large industrial and commercial complexes.

Use alarms with integrated audible and visual signals to accommodate the hearing and visually impaired, and for areas where a person may be working alone. This includes areas such as restrooms, storage areas, offices, and similar areas.

Audible Notification

Audible notification is a method of providing occupant notification of fire. In order for audible devices to alert the building occupants, the device must be loud enough to be heard. The level of loudness is a measurement of sound pressure and that measurement is in decibels. The decibels produced by a notification device are expressed as dBA.

NFPA® 72 requires the sound level to be at least 15 dBA above the average or normal sound level or 5 dBA above the maximum sound level that lasts at least one minute in the protected occupancy. The total sound pressure produced by the audible devices must not exceed 120 dBA because permanent hearing damage may occur above this level.

If the ambient sound in a building is above 105 dBA, the building must have visible notification. NFPA® 72 allows the audible notification in noisy areas if the ambient sound level can be reduced (such as a night club).

This measurement is required to be made at 5 feet (1.5 m) above the floor. The measurement in sleeping areas is required to be measured at the pillow level. The Average Ambient Sounds levels for various types of occupancies are given in **Appendix H** and should only be considered a guide. Each installation will require specific evaluation.

Visual Notification

The requirement for specific visual notification appliances comes from the adopted building code. The strobe requirements of the ADA apply to new construction and renovations to portions of buildings open to the general public **(Figure 14.51)**. Likewise, the ADA requires visual alarm notification devices in portions of any building accessible to a hearing impaired person. In commercial facilities, visual alarm notification appliances would be located in areas accessible to the public and to occupants of the facility who may have a hearing disability. Areas such as conference rooms, restrooms, hallways, routes of tours, and the private office of someone with a hearing disability are examples. When visual alarm notification appliances are required, the installation, operation and location requirements are the same for both the ADA and NFPA® 72.

Figure 14.51 Strobe requirements apply to areas that are open to the public. *Courtesy of Rich Mahaney.*

Candela Information

The light intensity of a visual device is measured in candela (cd). The appliances listed for evacuation have specific light output requirements that must be complied with for the listing. Power is applied to these devices and the light output is measured to ensure the proper light output. The minimum light directly in front of the device is 15 cd.

Visual alarm notification appliances are installed in one of two orientations: wall mount and ceiling mount. Visual notification appliances are listed for a particular orientation and are required to be installed in that orientation.

Requirements for Wall-Mount Devices

Wall-mount devices cannot be mounted on ceilings for visual notification. Wall-mount devices are required to be mounted between 80 and 96 inches from the finished floor level. The spacing requirements for the visual devices are based on the tables in NFPA® 72. The spacing is based on the square area covered by a single appliance. The area of notification is determined when the device that entirely covers that area is used. As an example, a room is 40 feet wide by 20 feet deep. The room would be required to have a minimum of a single 60-candela strobe or two 30-candela strobes on the shorter sidewalls opposite of each other.

When visual appliances are mounted on the walls, the strobe configuration is one, two, or four devices per area. NFPA® 72 has tables that define the minimum required light output. Generally, the largest room area covered by a single wall-mounted device is 70 feet by 70 feet. The maximum room area covered by a ceiling mounted strobe is 50 feet by 50 feet. In addition, the strobe must be mounted in the center of the room to achieve the light levels as specified in the tables in NFPA® 72.

Figure 14.52 The inspector should verify correct placement for visual devices.

Where required, visual notification appliances must be installed in corridors that are less than 20 feet wide **(Figure 14.52)**. If the corridor is wider than 20 feet, the requirements for room spacing are applied. The minimum candela rating for the visual appliances mounted in corridors is 15 cd. The visual devices must be mounted within 15 feet of the end of the corridor and must not be spaced more than 100 feet apart on center. They must be mounted in accordance with NFPA® 72 for the proper height and placement. In addition, if there are any interruptions in the corridor, such as fire doors, partitions, or changes in elevation, the areas are to be viewed as separate areas.

The fire inspector must be observant with how visual appliances, and strobes in particular, are installed. When more than two strobes are in the field of vision, the strobes must be synchronized to flash at the same time. Some people are prone to photosensitive epileptic seizures when exposed to random flashing lights and synchronization of audible signals and strobe flashes prevent a potential seizure in these individuals.

The inspector should also recognize that certain visual notification appliances are field adjustable for a range of candela values. The inspector should verify that the correct candela setting is made. This information should be shown on the approved plans.

Required Detection and Alarm System Documentation

When fire alarm systems are installed, plans for the complete fire detection and alarm system should be submitted for review and approval by local authorities. The submitted plans should include building dimensions to scale with partition walls, duct work, and separation barriers. In addition, a point-by-point initiating device detail should be submitted showing:

- Detector placement
- Notification device placement
- Sequence of operation

- Voltage drop calculations
- Battery calculations

Manuals and manufacturers' cut sheets should be also be submitted for review and approval. When the system installation is completed, an "as-built" drawing should also be provided to at least the property owner and a Record of Completion should be provided to the local authorities.

On newer fire detection and alarm systems where the system installer has used computers to program the panels, additional design details should be submitted. The design configuration of the system in the building should be given to the building owner and remain on site. This is to verify that the panel can be reconfigured to the exact way it was designed and built if a catastrophic failure occurs in the panel. In addition, the system should be completely tested anytime a change in the software is made to verify that it is operating as designed and originally intended.

Chapter Summary

The inspection of fire detection and alarm-signaling systems is an almost daily activity for the inspector. This chapter described the fundamental components and operation of these systems. The procedures that must be used while conducting inspections and tests of these systems have also been provided. Many unique situations may demand a particular type of system or initiating device within the community's jurisdiction. The fire inspector must be familiar with these conditions and the systems that have been installed.

Review Questions

I

1. What is the basic function of the fire alarm control unit (FACU)?
2. List types of notification appliances.
3. Name types of alarm-signaling systems.
4. List types of heat detectors.
5. Names types of smoke detectors.
6. List types of flame detectors.
7. What are the placement requirements for manual pull boxes?
8. Name some of the general inspection considerations for a fire inspector.

II

1. What should an inspector witness during an acceptance test?
2. List inspection requirements for different types of occupant notification devices.